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W. R. STRICKLAND, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

Vol. XXV December, 1929 No. 6

CONTENTS

The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.

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Transportation's Urgent Needs Analyzed

Toronto National Transportation Meeting Focuses Scientific Attention on Basic Factors of Motor-Vehicle Development

A PROGRAM overflowing with automotive interest was unfolded at the Royal York Hotel in Toronto, Canada, Nov. 12 to 15, as the Transportation Meeting of the Society progressed. Beginning with the Motorcoach Session held Tuesday morning and continuing until late afternoon on Friday, the eight technical sessions and the Transportation Dinner on Thursday evening kept the more than 300 members and guests who attended the meeting almost continuously occupied.

Motorcoaches, bodies, six-wheel vehicles, freight and passenger transport, engines, governors, brakes and maintenance methods were subjects thoroughly considered in their broad aspects and, together with the many interesting points threshed out in the animated discussion which followed the presentation of the various papers, a mass of data concerning technicalities and methods was made available that will require months to digest and assimilate. Its high quality is evidenced by the several papers that are published in this issue of THE JOURNAL.

The two joint sessions on Nov. 13 with the members and guests of the Motor Transport Division of the American Railway Association constituted an unique feature in that this was the first event of its kind, and the interchange of ideas between railroad and automotive engineers doubtless will result in a better understanding of and cooperation in their mutual problems.

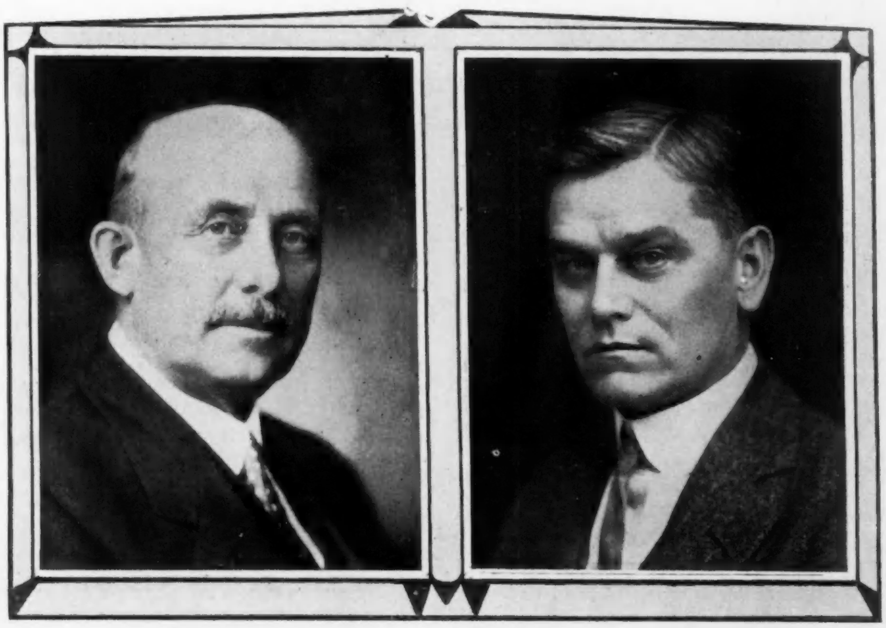
Workers Who Made Sessions Interesting

The splendid support of the Canadian Section and the untiring effort of its officers and members toward making the Transportation Meeting a complete success culminated at the Transportation Dinner, at which the Section members constituted themselves hosts to all those attendant at the meeting. R. H. Combs, Chairman of the Section, proved himself a genial and able toastmaster and contributed a large share toward creating the spirit of conviviality and good fellowship that pervaded the assemblage. Indeed, the Section is to be heartily congratulated on the success that crowned its efforts, which no doubt will be attested by each person who was fortunate enough to have attended, and that these efforts were thoroughly appreciated is thereby proved.

Members who attended the meeting are indebted for the great fund of valuable information presented and the general success of the occasion to F. C. Horner and other members of the Transportation Committee who collaborated in arranging the program and securing the authors and speakers, and to the men who gave so largely of their knowledge and time in preparing the papers. Unstinted appreciation of and thanks for their efficient conduct of the numerous sessions are due to the following Chairmen:

A. S. McArthur, Vice-Chairman of the Canadian Section; A. P. Russell, Chairman of the Motor Transport Division of the American Railway Association; Mr. Horner; J. F. Winchester, who presided at two sessions for which he was scheduled and substituted most ably for both Mr. Russell and Mr. Horner at the second Joint Session; A. A. Lyman, who very capably filled the chair at the Body Session in the absence of Martin Schrieber, who could not attend the Transportation Meeting; and F. K. Glynn, A. J. Scaife and A. Ludlow Clayden, who most acceptably filled the void at the Maintenance Session created by the illness of Mrs. Preble which prevented the filling of the chair by T. L. Preble, a member of the Transportation Committee of the Society.

Throughout the week the Reception Committee



SPEAKER AND TOASTMASTER AT THE TRANSPORTATION DINNER

The Hon. George Stewart Henry, Minister of Public Highways of the Province of Ontario, Who Made an Address on Highway Improvement in the Province; and R. H. Combs, Who Presided as Chairman of the Canadian Section, Which Was Host at the Thursday Night Dinner

Meetings Calendar

National Meetings of the Society

Annual Dinner—Jan. 9, 1930
Hotel Pennsylvania, New York City

Miami, Fla., Aeronautic—Jan. 14, 1930
Miami Biltmore Hotel

Annual Meeting—Jan. 20 to 24, 1930
Book-Cadillac Hotel, Detroit

St. Louis Aeronautic—Feb. 18 to 20, 1930

Detroit Aeronautic—April 8 and 9, 1930

December Section Meetings

Buffalo Section—Dec. 3

Statler Hotel

Pre-manifold Vaporization—George Autenreith, Associate Professor of Machine Design; and Harry Baum, Associate Professor of Electrical Engineering, College of the City of New York.

Cleveland Section—Dec. 9

Front-Wheel Drive

Dayton Section—Dec. 18

Automotive Vehicle Riding-Qualities and Shock-Absorbers—E. F. Rossman and Walter F. Whitman, Delco Products Co.

Detroit Section—Dec. 9

Book-Cadillac Hotel

Commercial Instinct in Automobile Engineering—H. S. Vance, Studebaker Corp.

Indiana Section—Dec. 12

Engineering Problems of Producing Riding Comfort—By a member of the Purdue University Faculty. Papers or informal talks on Springs and Shock-Absorbers.

Metropolitan Section—Dec. 19

A. W. A. Building, 357 W. 57th St., New York City. Dinner at 6.30 p. m.

Navy Aircraft-Carrier Fxperience Applied to Civil Aeronautics—Lieut. L. D. Webb, U. S. N.

Speed Flying—A short talk by Lieut. Al. Williams, the Navy Ace.

Milwaukee Section—Dec. 4

Milwaukee Athletic Club. Dinner 6.30 p. m.

The Nitriding of Steels—R. Sergenson, Metallurgical Department, Central Alloy Steel Corp.

New England Section—Dec. 11

Kenmore Hotel. Dinner at 6.30 p. m.

Front-Wheel Drive—P. M. Heldt, Engineering Editor of *Automotive Industries.*

Northern California Section—Dec. 12

Engineers Club of San Francisco
Christmas Get-Together Party

Northwest Section—Dec. 14

Gowman Hotel, Seattle, Wash.
Subject—Transmissions

Pennsylvania Section—Dec. (?)

Geared Engines for Airplanes

Pittsburgh Section—Dec. 6

William Penn Hotel

Fleet Maintenance—J. F. Winchester

S.A.E. Club of Colorado—Dec. 10 (or 17)

Crankless Engines—A. M. Hall.

Southern California Section—Dec. 6

Six-Wheel Trucks; Their Types, Advantages and Disadvantages

Speakers—Ethelbert Favary, Moreland Motor Truck Co.; F. B. Tucker, President, Six Wheels, Inc.; and a representative of the Fageol Truck Co.

Wichita Section—Dec. 12

Hotel Lassen

Future Possibilities of the Liquid-Cooled Airplane Engine—Rex B. Biesel, Vice-President and Chief Engineer, Spartan Aircraft.

of the Canadian Section, serving at the various sessions in relays, assisted materially in the registration of those who attended and in receiving visiting non-members of the Society. Those who served on this Committee are A. S. McArthur, Chairman; Frank Averill, George J. Beattie, William Campbell, L. S. Usher, S. D. Ballard, C. E. Tilston, R. H. Curtis, W. A. P. Schorman, A. H. Foster and R. D. Lister. The Canadian Section also maintained a Section headquarters in the hotel during the week, where many of those who attended had an opportunity to meet and become better acquainted with one another following each day's sessions.

Motorcoach Development Reviewed

Passenger Transport, Application and Design Trends Featured at Motorcoach Session

WHAT change in design tends toward better earning power? was a question raised in Frank R. Fageol's paper at the Motorcoach Session which opened the Transportation Meeting. The author's answer was that the benefit of design changes is evidenced either in the form of reduced maintenance expense or a greater carrying capacity for the maintenance money expended. Following this introductory paper on the Trend of Motorcoach Design, which was read by Ross Schram, two other important papers were presented. F. C. Horner treated comprehensively the Application of Motor Transport to the Movement of Passengers, and Chester G. Moore read Dwight E. Austin's paper on Motorcoach Design from the Operators' Viewpoint.

A representative audience gathered in the Convention Hall of the hotel to greet the speakers and, following remarks by Chairman A. S. McArthur, of the Toronto Transportation Commission and by Mr. Horner on the general subject of transportation, the papers were presented and were amplified by the pertinent and informative discussions which followed.

Motorcoach-Design Trends

Mr. Fageol believes that the tendency toward change in design, whether in railroad, aviation, street-car or other practices, expresses itself more often in the larger units of these activities, as exemplified by the advent of double-deck motorcoaches. He has noted the expression of a definite desire throughout metropolitan cities to abandon the double-deck-motorcoach operations as a result of the advent of the so-called 40-passenger type of urban motorcoach at a weight commensurate with that of the 29-passenger motorcoach.

A representative metropolitan operating manager told him, wrote Mr. Fageol, that his company's decision to reduce the number of or to eliminate double-deck motorcoaches resulted from an analysis which showed that a single-deck 40-passenger motorcoach earned about 8 per cent more than the double-deck type, and that this increase was caused by the ability of the 40-passenger vehicle to accommodate, during peak hours, 25 per cent more passengers than could the double-deck vehicle; further, that the operating cost of the 40-passenger single-deck motorcoach was 12 per cent less than that of the double-deck type formerly used.

SPEAKER AND CHAIRMAN AT THE MOTORCOACH SESSION

Ross Schram, Who Read the Paper by F. R. Fageol on The Trend in Motorcoach Design; and A. S. McArthur, Chairman of the Session, Chairman of the Reception Committee, and Vice-Chairman of the Canadian Section

One representative railway journal has expressed editorially the belief that the two basic capacities of coaches would hereafter be 21 and 40 passengers, the author continued, and that the 29-passenger vehicle is seemingly eliminating itself from its former position of importance.

The Fageol company's presentation of the 40-passenger motorcoach with two small engines placed amidships and the body and chassis integral, according to Mr. Fageol, initiated a definite new and permanent trend in motorcoach design which furthered the recent general tendency toward the use of single-deck vehicles designed for larger reserve capacity. He stated his belief that the future motorcoach, as well as the motor-truck and the delivery vehicle, increasingly will be designed upon analyses of the particular transportation service involved.

Elongated Chassis Impractical

Lowered center of gravity, economy of street space and short turning radius are salient factors, and Mr. Fageol believes that the attempt to secure reserve capacity by elongated conventional motorcoach chassis will not prove practical. Maneuverability is lost in such cases, in some types the driver's vision is seriously hampered, and it seems impossible to keep the weight within reason. Much better results can be obtained for the larger motorcoaches by using two comparatively light-weight six-cylinder engines. He stated that automotive practice has not yet provided clutches, transmissions, driveshafts or rear-axle drive-mechanism sufficiently large and strong to withstand the stresses set up by a single 150-hp. engine.

Mr. Fageol is not sure that the present 40-passenger motorcoach represents the maximum size that will be needed for the future, but believes that the capacity probably will not be increased because it represents about the maximum size of vehicle that one man can operate conveniently, collect fares upon, and adhere to his schedule in a way acceptable to the riding public. He asserted that the correct large-

reserve-capacity vehicle must be found so as to make general motorcoach operation a success and furnish the margin necessary for the supplementary operation of small motorcoaches.

Motorcoach schedules can be adequately maintained without exceeding a speed of 45 m.p.h., according to the author. His company has recently developed a speed signal that warns the driver by flashing a light when the engines have almost reached their predetermined maximum speed and actuates a buzzer or bell when this speed is reached, so that the passengers are made indirect parties to proper supervision of the operation of the vehicle.

Driver Control Essential

Safety and control at dangerous speeds are not specifically an engineering problem of better brakes, said Mr. Schram in the discussion, but very largely a matter of driver control; the signal referred to by Mr. Fageol represents an effort to afford passengers a means of indirect control of driver operation. Mr. Horner agreed that driver control is extremely important, but also insisted that the brakes must be adequate in that the driver must have dependable machinery available in an emergency.

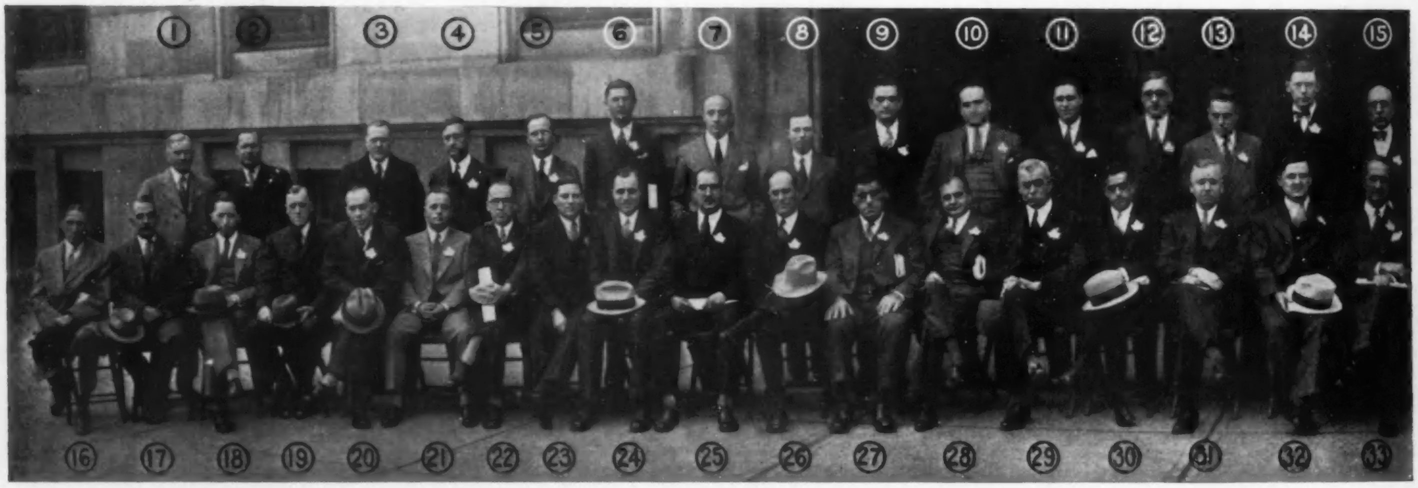
A. A. Lyman, of the Public Service Coordinated Transport, of Newark, N. J., remarked the tendency of passengers to urge a driver to travel faster, no matter how fast the vehicle may be running; but he suggested that if schedules are reasonable and well maintained so that travelers can with reasonable certainty reach their destination at a given time, this has a tendency to eliminate the evil.

Thomas S. Kemble, consulting engineer of St. Louis, questioned what the maximum deceleration provided by the braking system ought to be, stating that recent experiments indicate to him that a deceleration of 6 m.p.h. per sec. is about the maximum that can be employed, when the safety of the passengers is considered. He cited an instance in which a passenger standing in the middle of a motorcoach was thrown almost against the dashboard of the vehicle and flat upon his face following a sudden emergency application of the brakes, and said this was an indication that some maximum deceleration ability of a braking system should be specified for both city and interurban operations. He believes it is detrimental to have the brakes too powerful. On the contrary, A. W. Scarratt, of the International Harvester Co., said that, because so many hazards must be contended with on the road, the best brakes that can be provided are none too good to meet emergency conditions. His company attempts to provide a brake that will give a rolling stop, with the wheels just bordering on a tire slide or skid under maximum-load conditions on dry pavement. Mr. Horner suggested that operating companies that have had few or no accidents with motorcoaches should analyze the reasons therefor to determine exactly why the operation of the vehicles is successful.

Passenger Movement by Motor Transport

In presenting the present status of motorcoach transportation in the United States, Mr. Horner showed by data and charts the great growth in the last decade in the number of motorcoaches operated, the mileage covered and the number of passengers carried, and compared these with similar data for rail transportation and increase in urban population.

Operating-cost figures showing the relative economy of motorcoach operation as compared with steam-train service were given. The speaker mentioned that long-distance motorcoach lines are growing into important interstate and National systems and showed in tabular form the extent to which



GROUP OF MEMBER AND GUEST ATTENDANTS AT THE MOTORCOACH SESSION OF THE TRANSPOR-

(1) S. T. Westcott, Superintendent of Garage Department, Toronto Transportation Commission; (2) M. B. Mills, Sales Engineer, General Motors Truck Co.; (3) A. D. Ferguson, Bureau of Economics, Canadian National Railways; (4) Morris Buck, Engineering Editor, *Electric Railway Journal;* (16) J. O. Livingston, Associate Editor, *Bus and Truck Transport;* (17) Charles Morse, Toronto Transportation Commission; (18) H. J. Rymes, Superintendent, Central Ontario Bus Lines; (19) J. E. Reid, Mechanical Engineer, International Motor Co.; (20) F. C. McManus, Engineer, International Motor Co.; (21) H. V. Loveland, Assistant Body Engineer, Studebaker Corp.; (22) J. A. Packard, Commercial Car Engineer, Studebaker Corp.

(5) E. F. Loomis, Manager Truck and Bus Department, National Automobile Chamber of Commerce; (6) G. T. Hook, Editor, *Commercial Car Journal;* (7) F. W. Sevin, Sales Engineer, Vacuum Oil Co.; (8) C. Johnson, Jr., General Engineer, Auto Division, Westinghouse Air Brake Co.; (9) L. R. Buckendale, Executive Engineer, Timken-Detroit Axle Co.; (10) R. L. Morrison, Representative, Westinghouse Air Brake Co.; (23) Frank St. John, Bendix Aviation Corp.; (24) J. R. Bartholomew, Bendix Aviation Corp.; (25) G. C. Goode, Consulting Engineer, Chrysler Motors Corp.; (26) C. H. Taylor, Consulting Engineer, Bendix Brake Co.; (27) Austin M. Wolf, Consulting Engineer, Newark, N. J.; (28) A. J. Poole, Manager of Manufacturers Sales, Robert Bosch Magneto Co.

(11) A. Vance Howe, Representative, Westinghouse Air Brake Co.; (12) A. A. Lyman, Automotive Engineer, Public Service Coordinated Transport; (13) C. B. Veal, Research Manager, Society of Automotive Engineers; (14) R. E. Plimpton, Associate Editor, *Bus Transportation;* (15) F. H. Hazard, Publication Department, Society of Automotive Engineers; (29) H. V. Middleworth, Superintendent of Operations, Consolidated Gas Co. of New York; (30) John Walker, Engineer of Special Equipment, Mack-International Motor Truck Corp.; (31) A. S. McArthur, General Superintendent, Toronto Transportation Commission; (32) C. G. Moore, Eastern Representative, Pickwick Nite Coach Corp.; (33) F. C. Horner, Assistant to Vice-President, General Motors Corp.

city transportation-service is rendered by motorcoach, including also examples of operating costs and revenue. Considerations of the causes of delays in service, taxation of motor-trucks and motorcoaches, and restrictions imposed for the protection of highways and the users thereof were also presented. In conclusion, Mr. Horner stated that the science of the application of motor transport rather than the design, material and construction of the vehicle is our biggest problem today. The paper will appear in an early number of THE JOURNAL.

R. E. Plimpton, of *Bus Transportation*, asked during the discussion whether it is better policy for the steam railroads entering the motorcoach business to confine their efforts to the highways parallel to their main lines and their branches or for them to operate motorcoaches over a network of all the highways within their territory. In reply, Mr. Horner said in effect that many railroad officials feel that it is legitimate to operate within their own territory whether the highways parallel their lines or not, but that they do not feel justified in operating within the territory of other railroads. In Mr. Horner's opinion the best solution would be for the railroads concerned to cooperate and provide an adequate motorcoach service as a joint operation.

The question was debated as to who would bear the expense of interstate regulation if such regulation becomes effective, considering the question on economic grounds from the viewpoint of the operating companies as to how that added expense can be offset; but it was conceded that at present it is too early to determine whether the figure mentioned, namely, 2 cents per mile as the minimum, is a reasonable estimate. In the opinion of Chester G. Moore, the cost would be greater than that stated, at least at the start; but, after the hearings and granting of certificates, he thinks that the cost of interstate regulation would not equal the cost now placed upon the operator because of the constant necessity for combating so-called wildcat operation.

Motorcoach Design

Comfort, long life, low maintenance-cost and accessibility were the foremost factors governing the design, by Dwight E. Austin, of the Pickwick Nite Coach and Duplex Coaches. To this end the entire powerplant, including the engine, transmission, clutch, gearshift, control levers, gages, instrument board and fuel system, was assembled so that it can be removed and a similar unit substituted by two men in 15 min., and so that the front or rear axle, including the springs, can be changed in the same time. The driveshaft assembly can be replaced in 10 min. when the engine is out of the chassis. Similar accessibility is provided in the body design. The body and frame are built as one unit and entirely of metal.

In building these coaches a new principle is employed in that the inside section, the seat brackets and other parts are installed first and then surrounded by the shell; the exterior panels, windows, and the like are the last to be installed and the easiest to be repaired in the event of damage. Mr. Austin stated in his paper that suggestions for any seating arrangement that will increase the seating capacity without sacrificing passenger comfort or increasing the over-all dimensions of the vehicle will be welcomed.

Classification of Drivers

Following his presentation of Mr. Austin's paper, Chester G. Moore described the method of classifying drivers employed by the Pickwick System whereby new men entering Class B can progress to Class A, to Class AA and then to Class AAA, the pay in the different classes being at different rates dependent upon the men's efficiency and

TATION MEETING, ASSEMBLED IN FRONT OF THE ROYAL YORK HOTEL IN TORONTO ON NOV. 12

(34) E. J. Stone, Sales Engineer, General Motors Truck Co.; (35) R. S. Burnett, Standards Manager, Society of Automotive Engineers (36) C. S. Miner, Sales Representative, Railway Locomotor Co.; (37) Samuel Simon, Secretary-Treasurer, Fitz Gibbon & Crisp, Inc.; (38) E. S. Hall, Mechanical Superintendent, United States Bureau of Mines; (48) C. F. Clarkson, Secretary and General Manager, Society of Automotive Engineers; (49) R. H. Combs, President, Prest-O-Lite Storage Battery Co., Toronto; (50) A. H. Wood, General Motors of Canada; (51) G. W. Garner, Special Engineer, General Motors of Canada; (52) William C. Naegel, Sales Engineer, Lang Body Co. (39) P. E. Coffey, Statistical Assistant, Rapid Transit Department, Montreal Transportation Co.; (40) Thomas Kemble, Consulting Engineer, St. Louis; (41) B. W. Brodt, Sales Manager, Firestone Steel Products Co.; (42) Pierre Schon, Sales Engineer, General Motors Truck Co.; (53) C. B. Morris, Mechanical Engineer, Haskelite Mfg. Corp.; (54) E. D. Merrill, President and General Manager, Washington Rapid Transit Co.; (55) B. H. Eaton, Motor-Vehicle Superintendent, Bell Telephone Co. of Pennsylvania; (56) A. M. Orr, General Manager, Equitable Auto Co.; (57) G. M. Kryder, Bus Tire Sales Manager, Firestone Tire & Rubber Co.; (58) R. I. Raycroft, Manufacturers Sales, Firestone Tire & Rubber Co. (43) O. M. Brede, Director of Service, General Motors Truck Co.; (44) F. L. Faurote, Publicity Manager, Society of Automotive Engineers; (45) W. J. Duffy, Vice-President, Big 3, Inc.; (46) C. W. Stone, President, Stone's Express, Inc.; (47) J. H. Keene, Mack Motor Co. of Boston; (59) G. F. Mackay, Assistant Sales Manager, Studebaker Corp. of Canada; (60) C. C. Dixon, of Toronto; (61) A. W. Scarratt, Chief Engineer, International Harvester Co.; (62) G. M. Sprowls, Manager, Highway Transportation Department, Goodyear Tire & Rubber Co.

their freedom from accidents. This system has been very successful. He mentioned that the shutting off by a forward bulkhead of passenger observance of the road ahead, as practised in the coaches mentioned, has largely eliminated nervousness of passengers so that they can relax and enjoy riding in these vehicles. This is in line with the fact that railroad passengers relax and ride in comfort because they cannot see the track ahead.

The questions and answers that followed largely related to the details of driver control, personal freedom of a passenger while riding in a motorcoach of the type described, and the degree of comfort and satisfaction he can expect. Each berth in the so-called Nite Coach is 2 in. longer than a Pullman-car berth and is 25 in. wide. Ventilation is by means of a large fan which forces air taken in through the roof into each compartment.

The bulkhead behind the driver also excludes all the interior light from his compartment and eliminates reflections on the windshield. Another advantage is that the driver can ventilate his compartment independently and so maintain sufficient fresh air to enable him to remain constantly alert and fight off the tendency to drowsiness caused by too warm air and by the hum of the engine.

Night Travel and Road Repairs

A. M. Wolf, automotive consulting engineer, of Newark, N. J., asked for a description of the method of removing the powerplant on the road in case of emergency so that vital parts can be made accessible for repair. Mr. Moore said that tracks are laid from the front of the coach to the ground, the engine is slid out upon wheels on these rails, and can be rolled down them and pulled back into place by a winch. In case of a tire change, the wheel is lifted off

CHESTER G. MOORE,
Who Read the Paper on Motorcoach Design, by Dwight E. Austin, and Answered Questions in the Discussion

the ground by an hydraulic jack. A saddle is provided on the axle so that the danger of having the jack slip from under is minimized. The subjects of heating and ventilating were also considered in some detail, as well as the method of providing meal service and porter service.

In conclusion, Coker F. Clarkson remarked that not only is the general subject of transportation vitally important but, as it grows in scope and economic value, the operation and maintenance of motor-vehicles will become the basis upon which automotive engineers will develop the various benefits desired by the public in general.

Motorcoach and Truck Bodies

Desirable Construction Features of Both Types Discussed at the Body Session

GREATER attention is being given motorcoach and motor-truck body-design continuously and it is rapidly becoming one of the most important branches in the development of better vehicles, said A. A. Lyman, representative of the Public Service Coordinated Transport, of Newark, N. J., and Chairman of the Body Session which convened on Tuesday afternoon, Nov. 12. Operators are learning the importance of rider appeal, comfort, durability and safety in motorcoaches, and this applies also to motor-trucks, he continued. Although the present vehicles are wonderfully improved as compared with the early types, they cannot be said to be entirely satisfactory at present, and future developments are expected to accomplish even greater improvement. Mr. Lyman compared the all-metal body with the composite wood-and-metal type, saying that each has its advantage and that probably operating expense alone will determine which is the more desirable and what the particular field for each construction is.

Two papers on motorcoach body construction, by E. O. Dalzell, of the Bender Body Co., and by William Naegel, of the Lang Body Co., were followed by two papers on the construction of motor-truck bodies, respectively by John Walker, of the International Motor Co., and Samuel Simon, of Fitz Gibbon & Crisp, Inc.

Motorcoach Body Construction

Lantern slides exhibited by Mr. Dalzell illustrated changes in motorcoach bodies since about 1921. He said in part that at present it is doubtful if body builders are in complete agreement as to the best methods of construction and the best materials, but he hopes that freer exchange of knowledge and experience and the cooperation of all builders will result in rapid advancement toward more standard practice.

The ideal body should be of good appearance that will meet the demands of existing conditions, have maximum durability, be engineered and assembled so that repairs can be made quickly and economically, and should provide the utmost possible comfort and safety for the riders, in Mr. Dalzell's opinion. Efforts should be made in these ways to convince the public of the advantage and convenience of traveling by motorcoach instead of by private automobile. The present demand indicates as highly desirable a strong, tough-textured wood-framed body, strengthened adequately at the joints and other places of stress, with correctly designed metal corners, angles, toe brackets and posts with metal inserts; that the entire wood frame be properly treated for protection against dampness or rot; and that all exposed surfaces be sheathed with metal.

All-Metal Motorcoach-Bodies

The main strength-members of the motorcoach body described by Mr. Naegel are all-metal, but the floor and the roof are all-wood construction. One great advantage of using metal is that continuity of construction can be maintained largely without increase in weight due to reinforcement, because of the consistency of the strength of the metal. Mechanical joints between metal parts can be riveted, welded or bolted, and it is possible to calculate the actual strength of the finished connection. Further, metal is affected but little by climatic conditions as compared with wood. He cited instances of 29-passenger motorcoaches in which the metal bodies weighed from 300 to 430 lb. less than if made of wood. Greater safety in case of collision or in the event of fire is obtained by use of metal construction, and damages caused by collision are less severe.

It is at present a most difficult problem to design a motorcoach body that will act in unison with the chassis,

said Mr. Naegel. The usual motorcoach body has a stiffness of approximately seven times that of the usual chassis. In his opinion it will be necessary to redesign the present-day motorcoach body to make it a flexible unit that will act in conjunction with the chassis, to design a flexible connection between body and chassis, or to discard the old outrigger and cross-member design and make a so-called three-point suspension having cross-members or outriggers over each spring support at the rear, and a connection as near to the front rear-spring support as is possible; in the last case, the floor must be designed to carry the load independently of the chassis frame.

Mr. Naegel outlined the general characteristics of present designs of all-metal bodies, discussed the subjects of insulation designed to minimize drumming and temperature changes, and commented upon the interior finish. Interior finish and final trimming-materials of a motorcoach, including window sash, seats, floor covering and the like, constitute approximately one-half of the total body weight, he said, and must be adequately considered when the coach is designed. He concluded by saying that the successful design of metal bodies is largely dependent upon the type, the trade demands, and the cooperation between the operator, the chassis builder and the body builder in working out the designs.

Data on Preservatives and Flexibility

Replying to a question by E. D. Merrill as to the treatment necessary to protect wooden frames from dampness and rot, Mr. Dalzell said that an oil treatment is given all wooden parts and that preservatives also are used to cover the parts completely before the wood is sheathed with metal, both waterproof and animal glue being used on all mortised joints.

Mr. Lyman asked regarding the amount of flexibility between bodies and chassis, and Mr. Naegel quoted tests showing that this varies from ¼ to ¾ in. at the joints approximately 18 in. back of the front end of the rear spring. If the frame is given freedom to adjust itself and three-point suspension of the load is employed, much trouble will be eliminated.

A. W. Scarratt remarked that he was impressed with the similarity of the problems of motorcoach body design and the mounting of a body on a chassis with the problems in the design of passenger-cars for railroad use. In his opinion all of the fundamentals now being considered are those which have been experienced in railroad work. He stated that the ideal combination of motorcoach body and chassis will never be reached until the body construction is carried forward to the point of front support, which is the front axle. With suspension at the four corners it is almost impossible to eliminate frame weaving, especially if the forward end of the body terminates approximately 25 per cent of the distance back of the front axle; but if a body were carried forward to the front axle, it would be necessary to make the entire body construction rigid enough to absorb all of the road shocks if the body is supported at the four corners.

Motor-Truck Body Construction

Commercial bodies today are beginning to receive some of the consideration they need in the way of a balanced design of body and truck as a unit, but the problems of correct load-distribution, reduction of weight, flexible mountings and good appearance still remain, said John Walker. He divided commercial bodies into (*a*) standard bodies of the closed, rack and express types, all complete with their chassis, for light delivery-trucks; and (*b*) custom-built bodies for trucks of 1½-ton and larger capacity. Specifications for the second group are less well-defined because local body-builders are called upon by the customer to make a body to certain specifications and distribution of load does not receive adequate consideration.

SAMUEL SIMON
Who Gave a Paper on Motor-Truck Body Construction

Mr. Walker considered load distribution in connection with details of the way in which many trucks are sold, that is, the influence of the salesman on the customer and the conflicting requirements of the latter, and remarked that the type of the body and the capacity desired should be determined first, and then the proper wheelbase and the size of chassis to carry it; further, the pneumatic tires must be adequate.

It was stated by Mr. Walker that aluminum bodies are the best examples we have of the advantage of reduced body-weight, and he cited a few examples. In his opinion an all-aluminum body construction means a saving of 40 to 50 per cent in weight. The life of these bodies seems to be as great as that of the other bodies and the resale or scrap value is considerably higher. For custom-built bodies he believes that composite construction of aluminum, wood and steel will reduce the initial cost and still make possible substantial saving in weight.

The flexible mounting of bodies and cabs requires considerable development, in Mr. Walker's opinion. He gave instances of progress made in such development and said that motorcoach body mounting, which is developed farther than is that of commercial bodies, shows some good solutions of the problem. In conclusion he stressed again the importance of correct load-distribution and the need for cooperation of sales and engineering forces to achieve it, the possibilities of bodies and cabs of lighter weight, the value of flexible mountings, and the relation that these various factors have to the attainment of well-balanced vehicles possessing good appearance.

Style Consciousness for Trucks

Truck operators are increasingly becoming "style conscious" with regard to their vehicles, said Mr. Simon. Truck manufacturers have streamlined their chassis, they have torn a leaf from the passenger-car manufacturers' book and have "dolled up" their product, appreciating the tremendous sales appeal of beautiful lines and attention to detail of finish. Body construction has kept pace with this trend. In the light delivery-truck field, de luxe equipment is being turned out by the better builders. Body lines must be pleasing, dimensions in good proportions, the woodwork properly framed, the metal work applied perfectly and free from high spots and depressions, and the final paint-job must be perfectly done in true coach-style.

The speaker outlined the materials of construction available and said that chromium-plating is being universally used on exterior hardware of the better commercial bodies. With the exception of dumping and coal-carrying bodies, no definite trend toward all-steel construction has been shown. The present trend in design is to use materials of appreciably less weight when this can be done effectively, and Mr. Simon thinks that aluminum-alloy construction has much merit for certain types of motor-truck body.

As to other advantages of aluminum

as body material, reduced deterioration and the elimination of painting expense result in substantial savings. Mr. Simon believes that aluminum-alloy costs are on the downward trend and, with increased consumption of this type of material and larger production programs on the part of aluminum manufacturers, that the differential between aluminum and wood bodies will be further reduced. In his opinion a body of aluminum alloy, which has a greater modulus of elasticity than steel, will be far superior to an all-steel body in ability to withstand the weaving strains in large bodies mounted by rigid four-point methods on chassis that are operated over uneven road-surfaces.

Service-Organization Influences

J. F. Winchester suggested in the discussion that many bodies are custom built because some local builder acquired a reputation for doing that particular sort of work and the local operator likes to be guided to some extent by the advice of someone whom he knows. If the service organization for the locality had a representative of a suitable type, his influence with the local operator probably would increase the factory production. This type of service has been overlooked, said Mr. Winchester, but it should be recognized and followed up.

Rating and Dimensional Standards

Pierre Schon, of the General Motors Truck Co., gave a valuable description of the method of rating motor-trucks which is now practised by his company. He stated that the controlling dimension is the distance from the rear of the cab to the center line of the rear axle and that eight standard distances have been adopted for this dimension, which can be varied slightly either way above or below the standard dimension.

In conclusion, various opinions were expressed with regard to standard methods of rating and possibilities regarding some active effort along the line of standardization of dimensions such as wheelbase and chassis length.

Six-Wheel and Freight Problems

Joint Sessions with the American Railway Association Are Replete with Vital Data

TWO JOINT sessions with the Motor-Transport Division of the American Railway Association were held on Wednesday, Nov. 13, the Chairmen being, respectively, A. P. Russell, Chairman of the foregoing Division, and J. F. Winchester, for the Society. Consideration of all major phases relating to the six-wheel motor-vehicle occupied the attention of the audience of more than 150 members and guests who attended the morning session and four papers on the subject were presented, these being followed by a spirited discussion. Mr. Winchester presided alone over the afternoon session, at which the subjects of freight movement by motor transport, factors governing the construction and use of motor-trucks, and how State motor-vehicle commissions can help develop motor-vehicle transportation, were treated comprehensively.

In his introductory remarks, Chairman Russell stated that this was the first joint meeting of the A. R. A. Motor-Transport Division and the Society. He referred to the position of this Division as being rather unique in that its members are discussing problems which are competitive between members of the A. R. A. as well as problems regarding which some major executives in the railroad world hold diametrically different views. For these reasons he welcomed the opportunity presented by this joint meeting at which members of the Association and members of the Society, who are so intimately connected with furthering the methods of transportation, could interchange ideas freely. Alderman F. Baker, representing the City of Toronto, then addressed the members and guests present in behalf of Mayor Samuel McBride, welcoming them to Toronto and expressing the eagerness of the Mayor to cooperate in furthering the interests of the Transportation Meeting.

A. J. Brosseau, president of the International Motor Co., then addressed the assemblage in an informative speech in which he discussed briefly the broad subject of Transportation. One of his main conclusions was that motor-coach and motor-truck operation is not wise if either attempts to perform a service for which it is not as well or better equipped than is the railroad, or if either attempts to cater to a class of customers who prefer rail service. This has been attempted in some instances, he said, and has proved unsuccessful.

Papers Printed in This Issue

Six-wheel vehicles and semi-trailer combinations were classified and described by A. M. Wolf in his paper on the Structure of Six-Wheel Vehicles, which begins on p. 589. Load distribution, application of power, arrangement of spring suspension and of tires are factors included in the analysis, and consideration is given to the desirability of a conventional differential between the two driven-axles as well as to the advantages to be gained by substituting a differential in which the action is limited. L. R. Buckendale's interesting paper on Four-Wheel Drives for Six-Wheel Chassis begins on p. 583. Tires on Six-Wheel Vehicles was the subject chosen by G. M. Sprowls, and his paper begins on p. 600. F. C. Horner analyzed the Application of Motor Transport to the Movement of Freight in a comprehensive paper which begins on p. 611.

Direct Versus Contract Hauling

On this subject, and with regard to the definite relations, both economic and moral, between rail and highway transportation, written discussion by F. J. Scarr said in part that these, together with a consideration of the future trend of freight traffic, point to the conclusion that the railroads, as the chief producers of organized transportation, have a responsibility to themselves and to their stockholders to assume aggressive leadership in coordinating transportation over the highways with the rail movement. This leadership must develop coordinated highway transportation through the following successive stages: Contract hauling with existing responsible operations; assimilation of responsible operators into systems related to individual carriers, and the consolidation of all such systems into one large operating organization similar to, if not, the Railway Express Agency. It is important that those responsible for policy determination within the various railroads have a clear conception of this trend and future objective to permit the molding of present policies in conformity with the ultimate requirements.

A paper by Pietro Vigna, consulting engineer, of Italy, on the trend of Six-Wheel-Truck Design in Europe, was scheduled for the morning session but, owing to a most unfortunate circumstance, was not presented. Mr. Vigna, not being a citizen of the United States, was denied admission to Canada and his paper, which was forwarded to the meeting to be read, was returned to him.

Six-Wheel Motor-Vehicle Development

The conception in 1918 of the idea of placing the dual rear wheels of motor-trucks in tandem to circumvent insurmountable problems presented by side-by-side placement of very large pneumatic tires on heavy-duty trucks so that the trucks could be operated at the high speed that is feasible with pneumatic tires was attributed to Paul W. Litchfield by E. W. Templin, in his

paper. Active development by the Goodyear Tire & Rubber Co. resulted in a vehicle of this type which operated 10,000 miles in its first year and then was scrapped.

Mr. Templin, who was assigned the task of designing an improved six-wheel construction in May, 1919, described his first and succeeding designs up to and including that produced by the Six-Wheel Co., in 1924. He presented data of impact tests and measurement of stresses in road pavement as made by the Bureau of Public Roads with six-wheel pneumatic-tired trucks and four-wheel trucks fitted with various types of tire. In conclusion, he made the assertion that the six-wheel vehicle is the logical solution of the problem of hauling heavy loads economically without causing destruction of the highways.

Discussion of Six-Wheel Papers

A. J. Brosseau raised the question: What is the carrying capacity of a pneumatic tire? and asked also What is the prospect that the tire manufacturers can develop tires having greater capacity and longer life than those now in use? Replies to these were made by G. M. Sprowls and by J. W. Shields. Mr. Sprowls said that the amount of air in the tire really determines its carrying capacity and he sees little hope that the carrying capacity for a given size of tire can be greatly increased beyond that at present. Mr. Shields expressed the hope of the tire manufacturers that they can make tires that will carry heavier loads for greater distances, but he said that this depends upon the distance that will satisfy the operators. He went rather deeply into the subject of greater carrying-capacity and in conclusion said that dual tires have a great advantage over single tires on both four-wheel and six-wheel vehicles. He quoted prices on tires that would be required to equip a vehicle with single tires and with corresponding dual-tire equipment of the same capacity. Assuming a 42x9-in. single tire having a capacity of 5000 lb., he compared with this two 36x6-in. tires each having a capacity of 2500 lb., the two costing $103.60 as against $169.30 for the 42x9-in. tire. In other words, one can secure the same tire capacity at about 60 per cent of the cost. Regarding service, Mr. Shields said that experience indicates that considerably better mileage and less tire trouble can be expected from the dual equipment than from the single equipment.

Thomas S. Kemble gave a brief de-

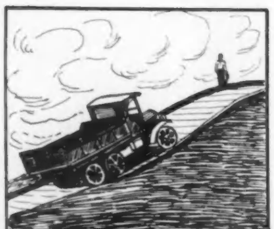
THOSE WHO TOOK THE MOST PROMINENT PARTS AT THE TWO JOINT SESSIONS OF THE SOCIETY WITH THE MOTOR TRANSPORT DIVISION OF THE AMERICAN RAILWAY ASSOCIATION

(1) F. C. Horner, Chairman of the S. A. E. Transportation Committee, and (2) A. P. Russell, Chairman of the Motor Transport Division, A.R.A., Joint Chairmen of the Two Sessions; (3) A. M. Wolf, Who Presented a Paper on The Structure of Six-Wheel Vehicles; (4) L. R. Buckendale, Who Gave a Paper on Four-Wheel Drives for Six-Wheel Vehicles; (5) E. W. Templin, Who Told of Early Six-Wheel Development; (6) G. M. Sprowls, Who Told of Service Given by Tires on Six-Wheel Vehicles; (7) B. B. Bachman, a Past-President of the Society, Who Presented a Paper on Factors Governing the Construction and Use of Motor-Trucks

scription of a gasoline-electric-drive six-wheel vehicle, the construction of which was started shortly after the Goodyear development of the six-wheel vehicle was begun. Its essential feature is individual drive for each of the four rear wheels, on account of which perfect differential action is obtained because each of the four electric motors can run a trifle faster or slower than the others. Regenerative electric-braking is employed and is effective from the top road-speed down to a speed of 5 m.p.h.; below this speed brakes located in the center between the electric motors are used. A. M. Wolf replied in considerable detail to a question regarding the effect of the various six-wheel constructions on the tracking and scuffing of tires.

Motor-Truck Construction and Use

B. B. Bachman explained that the term "motor-truck," as referred to in his paper on Factors Governing the Construction and Use of Motor-Trucks, applies to all mechanically propelled vehicles used for commodity transport. He reviewed briefly the different types of motor-vehicle best suited to special classes of business, also outlining the characteristics of the fields in which their service is most economical.



Regarding the trend of American motor truck design, Mr. Bachman stated that the general characteristics are tending gradually toward utilization of the same general principles as are followed in passenger-car design. In the last year or two the six-cylinder engine has been fitted to an ever-increasing number of motor-truck models because of the improvement in roads and the increased use of pneumatic tires. The principal mechanical and operating troubles, such as rapid wear of main and connecting-rod bearings, burning of valves, erosion of valve-seats and wear of pistons and piston-rings, are due to the high engine-speed demanded. The improved materials available for valves, together with the use of chromium and nickel as alloys in cylinder iron, promise to overcome the valve troubles previously experienced. Other factors and trends mentioned by the speaker included the subjects of piston and piston-ring wear, compression ratios, clutches, change-speed gears, gearbox bearings and materials for shafts. The present types of rear axle were described, and comments made upon the other parts of the vehicle.

In conclusion, Mr. Bachman predicted that the future probably will witness further increase in engine sizes and an increasing use of the six-cylinder and possibly eight-cylinder engines to meet the need for greater average road-speed without such a great increase in maximum speed. Such a requirement calls for more power to provide more rapid acceleration and sustained speed on hills. Improvement in brakes and the use of four-wheel brakes will naturally follow this increase in speed. Greater protection for the operator, more comfortable seats, and easier operation of the steering-gear and controls also will be demanded, in Mr. Bachman's opinion, together with better riding-quality and smoother and quieter engines, transmissions and rear axles.

Semi-Trailers and Differentials

In the afternoon discussion following that of the morning session papers, an outline of experience with semi-trailer operation was given by A. W. Kenerson, of the Standard Oil Co. of Ohio. Pierre Schon said, in reply to Chairman Winchester's question, whether by the application of a unit to a 5-ton truck the load can be doubled if tires of sufficient size are installed to carry that load, that a truck designed to carry a normal load of 5 tons cannot safely be converted into a 10-ton truck unless certain parts of the chassis are strengthened sufficiently.

Mr. Schon also noted that the manufacturers disagree regarding the need for a differential in the six-wheel vehicle between the two drive-axles. In E. W. Templin's opinion, the question is a practical one of whether it costs more to operate with a differential or without one, and his conclusion is that it is most practicable to operate without a differential. This was concurred in by R. W. Knowles, of the White Co., who also predicted that the future will witness more six-wheel vehicles of this so-called "fixed" type in use as well as an increasing number of semi-trailers.

An outline of experience with tractor and semi-trailer heavy-duty operation was given by W. G. Retzlaff, of the Fruehauf Trailer Co., who said also that the ideal unit for future long-distance freight operation may prove to be the six-wheel vehicle used as a tractor for a four-wheel semi-trailer. F. C. McManus, of the International Motor Co., outlined his company's experience with six-wheel vehicles.

Chairman Winchester remarked that the question of maximum over-all vehicle width is a very serious one, particularly on heavy vehicles, since the law in many States now limits this width to 96 in. One danger he foresees is that 3-ton and 5-ton trucks may be converted into six-wheel vehicles in which no extra brake power and no strengthening of the frame are provided, the result being an increased number of accidents and a general public objection to the vehicle.

State Motor-Vehicle Commissions

The subject of How State Motor-Vehicle Commissions Can Help Develop Motor-Vehicle Transportation was presented by Charles A. Harnett, Commissioner of Motor-Vehicles for the State of New York, in a paper that was read by his representative, A. W. Kallmeyer. Commissioner Harnett wrote in part that laws and regulations which affect the design, manufacture or operation of motor-vehicles usually result from suggestions made by, or are administered by, highway and motor-vehicle departments and, in the case of the motorcoach, by public-service commissions. Together with the police agencies of the State and its subdivisions, these govern the operation of vehicles and it is only through understanding of the functions, aspirations and limitations of these departments with respect to the motor-vehicle that difficulties arising from the regulations can be dealt with properly. He outlined the regulations existing between these departments in different States, and mentioned the influence the extension of paved roads and the widening and straightening of main highways have had on the rapidity with which the motor-vehicle is replacing other forms of carrier for short hauls.

Handicapped by Lack of Uniformity

Most of the corporations now operating motorcoaches are public-utilities organizations, according to Commissioner Harnett, and for that reason come under the jurisdiction of the public-service commissions. Among the various laws governing the action of public-service commissions are those which give the commissions the authority to adopt regulations compelling companies under their jurisdiction to furnish safe and adequate service at just and reasonable rates. Under such authority the public-service commissions have set up regulations designed for the protection of passengers in connection with the operation of motorcoaches, and they also have the power to compel the use of devices designed to promote the security and convenience of the public and the employees.

One of the great difficulties confronting motor-vehicle transportation is the lack of uniformity of the laws of different States, Commissioner Harnett continued, and in various localities in the United States organizations have been formed for the promotion of uniform laws. All regulations promulgated by a State administrator usually are given publicity, so that it should not be difficult for motor-vehicle organizations to keep informed.

Engines and Governors Featured

Heavy-Duty Engines and Types of Governor Studied at the Engine Session

NO ONE can predict when the ultimate limit of the constant tendency toward the increase in motor-vehicle traffic on our highways will end, although it is probable that in the near future legislation, induced by public sentiment, will attempt to call a halt, said Lewis P. Kalb, of the Continental Motors Corp., in presenting the introductory paper of the Engine Session, held Thursday, Nov. 14. Even should legislation succeed in this action, will still have the possibility of super-highways reserved for fast traffic, on which speed much higher than any attained thus far not only will be permitted but encouraged. It is in the commercial vehicle field that this trend has been most marked, according to Mr. Kalb, the principal reason being the tremendous growth in the operation of intercity motor-trucks and motorcoaches.

Following the presentation of Mr. Kalb's paper on Six-Cylinder Motor-Truck Engines, Chairman J. F. Winchester called upon A. A. Bull, of the Handy Governor Corp., who presented his paper on the Application of Engine Governors to Transportation Equipment, and numerous engineers specifically interested in these subjects participated in the discussion which followed.

Six-Cylinder Motor-Truck Engines

Mr. Kalb quoted interesting statistics relative to the increase in the road speeds of motor-trucks as compared with those of six years ago, which were 25 m.p.h. for all vehicles operating on pneumatic tires and 15 m.p.h. when operated on solid tires. Today, 35 to 40 m.p.h. is believed legitimate for even the heaviest vehicles, and the lighter or so-called speed trucks are expected to be capable of speeds as high as those of most passenger-cars.

The greater flexibility, wider range of power, and comparative freedom from vibration make the six-cylinder more adaptable to high-speed heavy-duty operation than is the four-cylinder engine, in Mr. Kalb's opinion. He outlined the reasons for the wider power-range of the six-cylinder engine and analyzed mathematically bearing-pressures resulting from combined centrifugal and inertia forces, which must be considered in determining the maximum speed at which an engine should be operated. The most effective method of limiting engine speed is by the use of a suitable gear-ratio, he said, although the designing of the engine so that it is incapable of running too fast is logical and, in his opinion, should be followed to a much greater extent.

The simplest and most readily determined index of the duty imposed on the engine is the ratio of the total load carried to the piston displacement, or the "load factor," said Mr. Kalb, and a survey of practice shows its values to range between 30 and 48 lb. per cu. in. for high-speed six-cylinder trucks, considering capacity load only. From his previous analysis he derived an equation expressing the load factor in terms of speed ratio and tractive factor, by means of which he showed that too small an engine will result in excessive engine-speed, insufficient ability, or both. In conclusion, he enumerated the desirable features of a satisfactory motor-truck engine, exhibiting lantern slides of charts and an engine specially developed for heavy-duty service.

Interest Centers on Oil-Cooling

In the discussion, A. W. Scarratt referred to the desirability of holding the temperature of the lubricating oil under maximum operating conditions to values of 175 to 180 deg. fahr. and asked how such a maximum temperature can be adhered to. One method effective in this direction was stated by P. F. Magoffin, of the Reo Motor Car Co., to be the use of aluminum instead of cast-iron pans equipped with cooling fins, by which means and the use of a large volume of oil in the pan it has been found possible to keep the temperature down to 10 to 15 deg. fahr. under the cooling-water temperature.

In connection with the design of an oil-cooler for a marine engine, A. H. Frost, of the Vacuum Oil Co., said that the cooler used a very thin film of oil and that, by passing water on both sides of this film, the cooling effect was very satisfactory and the temperature could be held down to about 120 deg. fahr.

Thomas S. Kemble remarked that the greatest difficulty with the high-speed operation of an engine is with engine temperatures only indirectly and is directly concerned with oil viscosity so that, in his opinion, the simplest method is to maintain a lower oil-temperature by the use of some temperature-regulating device; in other words, he believes the problem to be not simply a matter of cooling the oil but one of regulation of the oil temperature.

Application of Engine Governors

The two fundamental reasons for the use of governors on motor-vehicles are necessity and desirability, said A. A. Bull, in dealing with the subject of governors. He mentioned that a very definite acceptance of governor equipment exists on the part of both the manufacturer and the operator. He noted the marked change in the characteristics of powerplants in commercial vehicles that has occurred in recent years, analyzed the technical considerations that apply to the conditions at present, and listed the factors which determine whether the engine, the vehicle, or both shall be governed. He stated the four essential requirements of a governor to be that

(1) It must not affect the power of the engine at speeds below the full-load governed-speed.

(2) The speed difference between full load

SPEAKERS AT THE ENGINE SESSION

L. P. Kalb, Who Gave a Paper on Heavy-Duty Engines for Truck and Motorcoach Service; and A. A. Bull, Who Presented a Paper on Engine Governors for Transportation Equipment

and no load should be held to the minimum, but this difference should not be so small that hunting or surging will occur.

(3) In the speed intervals between maximum load and no load, running must be perfectly stable; that is, there must be no hunting.

(4) While ease of adjusting the speed setting must be given some thought, it must not be obtained at the expense of the other items mentioned.

After analyzing the relation of engine speed to road speed, Mr. Bull said that present-day governors are divided into two distinct classes—the mechanically driven centrifugal type and the vacuum or velocity type — and gave illustrations and descriptions of each. The mechanical construction of each was also described, the method of making governor calibrations was outlined, the operation of each type was explained and devices for determining governor speed-settings, which also are used as a means for inspection, were illustrated.

Governor-Regulation Effects Discussed

L. P. Kalb, referring to six-cylinder motor-truck engines designed for the higher speeds, remarked that the velocity-type governor of the present construction possesses many more advantages than it formerly had. Considering an engine which has a maximum torque at about 1200 r.p.m. of the governor, he said that the governor is set beyond the point at which it can impair the performance of the engine when operating at about 2000 r.p.m., and that a slight reduction from the maximum torque or a somewhat wider regulation is not harmful. But with maximum torque at 900 r.p.m. and the governor speed at 1050 r.p.m., very close regulation must be provided or the governor will impair the maximum torque and thereby reduce the capability of the engine. A. W. Scarratt mentioned that governors do not limit the engine speed under coasting conditions, and said that the greatest damage that is likely to happen to an engine occurs under coasting conditions of long duration. In reply, Mr. Bull said that, obviously, there is some restraint on the speed if under coasting conditions in low gear the throttle is closed and, he added, the governor functions in much the same way.

Replying to questions raised by Mr. Scarratt and H. P. McDonald, superintendent of automotive equipment for the Missouri Pacific Railroad, referring to the restrictions imposed on the maneuverability of a motor-vehicle equipped with a governor, Mr. Bull said that we must consider that the vehicle has some limit of speed and, regarding its ability to pass another vehicle which is traveling at about the same speed, the relative conditions are the same at say 50 m.p.h. as they are at 40 m.p.h.; however, he acknowledged that if the governed speed is set considerably below the average operating-speeds of vehicles in the territory, the maneuverability is disturbed.

A. J. Scaife suggested possible confusion of ideas in that a governor is installed to regulate engine speed and protect the powerplant, but that many regard the governor as a regulator of road speed. In his opinion, the governor's greatest value is during operation in the lower gear-ratios when ability is required on the different grades and when operating in the lower transmission-speeds, in that it prevents the operator from over-running the engine into a zone beyond the speed at which the engine operates most economically. Mr. Magoffin agreed with Mr. Scaife that the governor is a device to protect the engine and should not be thought of as a road-speed governor.

F. K. Glynn remarked that a governor is no substitute for adequate fleet-operator supervision and management of drivers. He believes that a governor should be set at some speed above that of maximum torque, the gear ratios selected to give appropriate speeds for the satisfactory operation of the particular type of vehicle, and drivers supervised to maintain a speed below a set maximum limit. Chairman Winchester characterized a governor as the most valuable and most reliable assistant a fleet supervisor can obtain, particularly in reducing up-keep cost. F. C. McManus stated his belief that a better policy will be for both the user and the manufacturer to regard a governor as a standard part of an engine and not an accessory.

Numerous arguments were presented by various discussers both for and against mechanical regulation of engine and road speeds. In conclusion, Mr. Kalb suggested that, since many engineers agree that speed limitation is a vital necessity, it is incumbent upon them to influence salesmen and customers to that effect.

Merits of Braking Systems Studied

Braking Requirements for Trucks and Motorcoaches Analyzed Constructively at the Brake Session

INCREASINGLY insistent demands for suitable and adequate braking mechanisms are caused mainly by the recent doubling of motor-truck road-speeds, the great increase in the number of vehicles in operation, and by the more strict traffic regulation, said G. B. Ingersoll, of the Federal Motor-Truck Co., in the introduction to his paper on Brakes for Motor-Trucks, which he presented at the Brake Session held Thursday afternoon, Nov. 14. His paper was a resumé of some of the various brake installations that have been used successfully on many different models of truck chassis.

The second paper was by George A. Green, of the General Motors Truck Co., on the subject of Heavy-Duty-Motorcoach Brake-Design. In the author's absence, this was read by C. O. Ball, of the same corporation.

Nearly 100 members and guests greeted the speakers and, following the presentation of the papers, Chairman J. F. Winchester called upon representatives of several brake-manufacturing companies, who presented prepared discussion bearing upon the subject.

Typical Commercial Brake-Installations

Different types of wheel brakes were illustrated and described with reference to mechanical details and operating features by Mr. Ingersoll, who then discussed propeller-shaft brakes in a similar way. Passing to the subject of brake-linings, he said that the ordinary types of brake-lining that formerly gave satisfactory performance are now quickly squeezed out under the present high brake-operating pressures so that the demand now is for a dense, compact, homogeneous brake-lining that will maintain adequate braking action and wear slowly and evenly under hot or cold and dry or wet conditions.

Referring to brake-drums, Mr. Ingersoll remarked the increasing demands for brake-drum material that will withstand the terrific friction, pressure and resultant heat now encountered in heavy-duty service, and outlined the characteristics of materials available. Wheel-bearing lubricants was another subject discussed in relation to means of preventing their contact with brake-drums and brake-linings.

The speaker recommended that consideration be given to the use of the engine as an auxiliary in securing better brake-operation. Since the large vehicles now used are connected through the power-transmission mechanism to the rear wheels, he believes that the engine can be used economically as an auxiliary brake and thereby accomplish a saving in brake replacement-parts. He believes brakes for four-wheel motor-trucks will, in the near future, comprise four wheel-brakes and a separate propeller-shaft brake for emergency purposes.

The motorcoach must now provide a performance comparable with that of

J. F. WINCHESTER,

Chairman of Engine, Brake and One of the Joint Sessions with the Motor Transport Division of the American Railway Association

the average automobile and, since the coach must hold its place on the road with the passenger-car, the demand is not unreasonable, according to a statement in George A. Green's paper. Motorcoach and automobile brake problems were compared by Mr. Green, who also presented a logical analysis of the factors involved in the use of four-wheel brakes on motorcoaches. In analyzing the different systems of braking, both the advantages and disadvantages of the conventional forms of brake-operating mechanism, namely, the mechanical, the compressed air and the hydraulic systems, were listed and commented upon, and the merits of the materials used were compared. Metal-to-metal and propeller-shaft brakes also were considered, as well as brake-lining material; but only the principles were referred to, no attempt being made to describe design details.

While real progress has been made respecting brake problems in general, Mr. Green stated that a large amount of work remains to be done and that, although we seem to have emerged from a condition in which brakes were unsafe to a stage in which reliability can be confidently predicted, designs generally are crude. In conclusion, the author predicted future developments of braking systems for heavy-duty motorcoaches and stated their probable general characteristics.

Representative Opinions Stated

Preceding the general discussion of the foregoing papers, prepared discussion was read by the representatives of several different types of braking system. George Ainsworth, of the Bragg-Kliesrath Corp.; C. H. Taylor and H. D. Hukill, of the Bendix Brake Co.; S. Johnson, Jr., of the Westinghouse Air Brake Co.; and H. C. Bowen, of the Hydraulic Brake Co., submitted contributions.

Mr. Ainsworth took exception to some of the statements made in Mr. Green's paper, one being that the most successful operating medium for heavy-duty motorcoach brakes is compressed air. Mr. Ainsworth believes that the statement should more properly be "compressed air *and vacuum*." In Mr. Ainsworth's opinion the statements in Mr. Green's paper regarding the advantages of the air brake as a power unit apply equally well to the vacuum brake, which has advantages that cannot be obtained with compressed air.

Mr. Taylor stated that the ideal brake-mechanism is one in which the front wheels slide first under all terrain conditions with the steering-gear in the straight-ahead position, and wherein the front brakes become rapidly less effective as the steering angle increases. He mentioned one braking system, used successfully abroad but which has had virtually no development in the United States, that comprises the usual four wheel-brakes and a transmission brake. The transmission brake includes a resilient anchorage whereby the torque in either direction is used to apply the four wheel-brakes. By this arrangement almost unlimited power is available for applying the wheel brakes in a simple direct way. The hand brake in this case can operate directly on a cross-shaft to set either two or four brakes.

Booster Unit Has Merit

In addition to the brake combinations mentioned by Mr. Green in his paper, Mr. Hukill suggested one other combination which seems to possess considerable merit; that is, a central booster-unit, of the vacuum, air, electric or mechanical type, as may best fit the existing conditions, operating internal expanding-shoe brakes at the wheels through a cable-and-conduit control-system. He said that such a combination fits into the picture ideally where the independent hand-operated propeller-shaft brake is provided. This combination also incorporates the various advantages listed in Mr. Green's paper for air and hydraulic brakes, at the same time eliminating the disadvantages attributed to such systems.

Mr. Johnson stated that reliability of the air compressor is an esential for the success of the air-brake system, and specified the important requirements which must be considered in its design. He commented in some detail upon the statements made in the paper.

Mr. Bowen disagreed with the idea expressed in Mr. Green's paper that, because the railroads are using motorcoaches and are familiar with the air brake in railroad operation, they should use the air brake on motorcoaches. This might be modified to include the use of hydraulic brakes for motorcoaches, in Mr. Bowen's opinion. He stated that with hydraulic brakes it is a simple matter to check the pressure exerted on the brake-shoe. In the case of the brake made by his company, this pressure varies from 1700 to about 3100 lb. for the different sizes of brake-shoe, and he remarked that these pressures are entirely feasible and satisfactory. In his experience any standard brake-lining will score the brake-drum if the pressure is great enough but, if the pressure per square inch on the brake-lining is kept low enough, the lining will work satisfactorily. If tires of larger diameter are substituted for the original equipment they necessarily require increased pressure on the brake-shoe to make a satisfactory stop, and this causes drum scoring.

Brake-Shoe and Drum Contact Debated

In the general discussion, A. J. Scaife questioned the advisability of using the full 360-deg. contact between brake-lining and brake-drum and suggested that it might be better to use wider brake-shoes without surrounding the drum entirely by them, thus providing for a better circulation of air and therefore better cooling.

G. B. INGERSOLL,

Who Presented a Paper on Brakes for Motor-Trucks

G. B. Ingersoll thinks that the secret of efficiency and length of life of brake-shoes and brake-drums lies in the channel-section type of shoe having increasingly high side walls

which give an almost perfect circle in its closed and expanded positions, as this results in equal pressure throughout the entire contact surface of the drum. George Ainsworth reminded the audience that the total power developed and applied to the braking surface will result in a unit pressure per square inch that is commensurate with the area of the brake-lining which engages the brake-drum. He said that therefore the full contact area between brake-shoe and brake-drum is very desirable because it results in a lower unit pressure, which tends to prolong the life of the brake and to maintain a higher standard of deceleration even under the most extreme conditions.

Desirable Tire and Rim Diameters

A. W. Scarratt referred to Mr. Ingersoll's recommendation for serious consideration of the 22-in. series of tires and rims for heavy-duty trucks to improve the heat-dissipation effects, and asked when a complete series of 22-in. tires will be available. G. M. Sprowls replied that such a series already is available in the balloon type but that, although the 22-in. high-pressure tires can be made, so far there has been no demand for them. He said that in both motorcoach and motor-truck service the balloon type is giving very good service, especially in long-distance work, and that the manufacturer is governed by what his customers want.

J. W. Shields stated that he finds almost universal agreement that the tire having the larger rim-diameter is preferable; that is, a 24-in. rim is preferable as regards tire service to a 22-in. rim, which also is preferable to a 20-in. rim. He remarked further that reducing the rim diameter 1 in. reduces the service value of the tire by approximately 10 per cent. On this basis, a tire of 20-in. rim-diameter of the same cross-section construction operated under the same service conditions will give 20 per cent less service than will a corresponding 22-in. tire.

W. G. Retzlaff, of the Fruehauf Trailer Co., stated that no one has so far made figures available which will specify the amount of deceleration from a certain speed that a given braking mechanism will effect for a gross load of 1000 lb. Therefore, this question has been left entirely with the operator, whose engineers must choose their braking mechanism by rule of thumb. He raised this point in connection with the stopping of a 120-hp. tractor-trailer train carrying a pay-load of about 20 tons and traveling between 25 and 40 m.p.h. In conclusion, H. C. Bowen mentioned some of the difficulties of brake design with regard to calculations of brake performance. He said that so many factors enter into this problem that it is largely futile to attempt to predict the actual performance by calculations; hence, this matter is largely one of approximate design and trial.

Gala Transportation Dinner

Canadian Section Is Host to Road and Rail Men—Minister Henry Discusses Highway Development

THE splendid reception and attention given by the Canadian Section to those attending the Transportation Meeting were excellently exemplified by the dinner held at the Royal York on Thursday evening. The Section is very happy in its leadership. The dinner was virtually the occasion of the celebration of the first anniversary of the organizing of the Section. All did homage to Chairman Combs, Vice-Chairman McArthur, Treasurer Wood, Secretary Hastings, and many others of the Section.

Mr. Combs, president of the Prest-O-Lite Storage Battery Co., Ltd., presided at the dinner, which rounded out the program of valuable as well as very interesting professional sessions covering a surprising number of the vital phases of the engineering of highway transportation. Many representative railroad men were present at the dinner.

Mr. Combs, referring to the general problem of the adapting of automotive apparatus to the many environments throughout the world, and to the need for developing to the utmost the possibilities in this connection as soon as possible, mentioned the marked changed and changing attitude of the railroads toward highway motor-vehicle passenger and freight haulage, conducted independently of or by the railroads.

Ontario's Highway System

The Hon. George S. Henry, Minister of Public Highways for the Province of Ontario, was introduced by the toastmaster as the backbone of highway motor-traffic development in Ontario. Mr. Henry gave a very clear and convincing statement as to progress in road building in the Province from the standpoint of economics. He mentioned that motor-vehicle development has not decreased but increased railroad traffic, 3,500,000 carloads of shipments of automotive products having been made in the United States last year. The highway is of course basically essential in motor-vehicle trade. The Province of Ontario, though small and relatively new in road development, is making good progress. Of the 1,000,000 motor-cars in Canada serving 9,000,000 people, Ontario, representing one-third of the Dominion in population, has one-half of its motor-vehicles. The province is peculiarly and favorably situated in relation to the highway traffic of the United States.

Mr. Henry expressed appreciation of the cooperation, assistance and advice his department had received from highway organizations of our Country, with the result that the Province is in a very good position, with comparatively small road-mileage; higher standards of building being followed than would be the case otherwise. The number of motor-cars per capita in Ontario, he said, equals the average throughout the United States; namely 1 to 7. The entire population can be moved by road vehicles in one load each.

The Canadian railroads, said Mr. Henry, are studying the needs as to highway motor-transport, having the experience in the United States in mind. They make large use of motorcoaches and motor-trucks as auxiliary equipment. With subsidiary transportation, the ultimate consumer has more direct and perhaps better service.

Governmental Regulation

Since 1925 the Province of Ontario has endeavored to develop, as well as control, motorcoach transportation. Practically all the motorcoach operation is licensed and controlled, exclusive franchises with protection from undue competition being granted. This has enhanced the value of the franchises, some of which have been sold at a profit. There are 88 motorcoach licensees in the Province, 46 routes, and 600 vehicles. Tolls are paid based on street-miles, schedules over certain routes, vehicle size and number of trips. The factors give a definite idea of cost; also fair assurance of service to the public, as the tolls must be paid whether the vehicles are operated or not. The rates of fare charged are subject to supervision; and reasonable standards in type of vehicle, and the purchasing of insurance to protect passengers, are required.

Mr. Henry said that the service is

(*Continued on p. 683*)

Five-Day Annual Meeting Planned

Sessions Sponsored by Meetings Committee and Professional Activity Committees Promise a Representative Program

(Details of the Program Are Shown in the Enclosed Supplement)

A VERY few years ago it was customary for the Society's Annual Meeting to open on Tuesday and close after the Thursday evening session. Later, the number of sessions necessary to meet the needs of the members exceeded the time available in the three-day period, so the Meetings Committee decided to continue the meeting until Friday evening, thus adding another day to the time allotted for the Annual Meeting. For a while the four-day period sufficed, but when the program for the 1930 Annual Meeting was being arranged it was found that the interests of the members have become so broad that the number of sessions believed to be desirable cannot be accommodated in a four-day meeting; therefore the Meetings Committee has decided to add an extra day at the beginning of the meeting. Thus the meeting that is to be held in January will open on Monday, the 20th, and continue through Friday, the 24th, and for the first time the Society's Annual Meeting will be a five-day event. The enclosed supplement in this issue gives details of the arrangements for the meeting as they have been completed to date.

Interesting Body Events Planned

The success of one afternoon and evening of the meeting is already assured by the fact that the body men are sponsoring an afternoon conference, a dinner and an evening session. The afternoon program is being planned by the Passenger Car Body Committee; the dinner and the evening session, by the Body Division of the Detroit Section. The dinner and entertainment will be of a quality in keeping with that of similar events staged by the Detroit Section, and the technical events will be of exceptional interest.

The other sessions of the meeting promise equally well. The program for them, as shown in the inclosed supplement, are being prepared respectively by the Meetings, Passenger-Car, Research, Aircraft, Aircraft-Engine, Production, Diesel-Engine, Transportation and Maintenance, and Motor-Truck and Motorcoach Committees. Thus the program of the 1930 Annual Meeting will be truly representative of the various activities and interests of Society members.

Subjects about which little need be said at this time, as they speak for themselves, are such timely ones as front-wheel drive, mixture distribution and down-draft carburetion. A paper has been scheduled on each of these topics and a lively discussion is expected to follow the presentation of each paper. Inventions will be the topic treated in still another paper, in which many interesting facts about the work of the New Devices Committee of the General Motors Corporation will be told.

An entire session is to be devoted to the subject of Diesel engines, and various phases of this important topic will be dealt with in three papers by leading authorities in this field, as shown by the Meetings Supplement.

Important Topics at Research Session

One of the most practical, readily-applicable reports the Society has ever had from the Bureau of Standards as a result of the cooperative fuel research will be presented at the session sponsored by the Research Committee. A session on the ever-important topic of detonation is also being arranged.

A high-spot in the thorough and authoritative discussion of riding-qualities that has been planned will be Dr. Fred A. Moss's presentation of the method he has developed for measuring fatigue. This method, which has resulted from extensive research, promises to be of superlative value to the entire industry. At the same session, a paper on the elimination of chassis vibration will be presented.

The announcement that Louis Illmer will release at the Annual Meeting the data he has obtained as the result of several years' investigation will be a most welcome one to many members who will be interested to hear him present his material on friction-coefficient research. Discussion of this splendid paper will come from the Chrysler Corp.

Transportation and Production Subjects

A session has been scheduled for the transportation men, for whom a most interesting program has been arranged. The Transportation Session will consist of one exceedingly vital paper, followed by well-organized discussion.

A casual glance at the program, revealing the fact that Dexter S. Kimball, of Cornell University, is to talk on The Economics of Production, may leave a vague or a false impression as to the significance of this item. Everyone is interested in some way in mass production and many are wondering where it will lead. Such persons should let nothing prevent their hearing Dean Kimball's address, as he is said to have a better vision of the future of Americas mass-production methods than any other man living. His address, which will be instructive and entertaining without being high-brow, will constitute an entire evening's program.

Another evening session that promises to be of wide appeal is the General Session at which the only speaker will be Alfred Reeves, General Manager of the National Automobile Chamber of Commerce. Mr. Reeves will talk on the exceedingly vital and interesting topic, What 1930 Offers to the Motor Industry.

Likewise, the session that is being sponsored by the Aircraft and Aircraft-Engine Committees will be held in the evening, and the subjects treated will be sufficiently non-technical to be of general interest.

Two papers have been scheduled for the metallurgical session, one dealing with the relation of foundry practice to engineering and the other with tungsten-carbide steel in production.

A list of the papers to be presented at the meeting and the names of the men who will present them will be found in the supplement which accompanies this issue of THE JOURNAL.

Annual Dinner Arrangements

AS USUAL, the Annual Dinner is to be held on Thursday evening of the National Automobile Show week in New York City. The date is Jan. 9.

The reception is to start at 5:30 p.m., and the dinner will be served at 6 o'clock. These hours met with so much approval last January that they will be repeated. As the dinner and speeches will be concluded early, plenty of evening hours will remain in which those who attend the dinner can go to the Automobile Show or to the theater if they so desire.

This winter the Annual Dinner will be given for the first time in the Pennsylvania Hotel, where excellent facilities are available. The Waldorf-Astoria is now being wrecked, preparatory to the erection of a commercial building which may be the tallest in the world.

Formal announcement of and reservation blanks for the Annual Dinner are to be mailed to all members of the Society shortly.

Chronicle and Comment

Participation in Section Activities

J. A. C. WARNER gave an excellent address at the organization meeting of the Pittsburgh Section on the subject of Section membership values and opportunities. His remarks were based on long experience and study. Copies of the complete address will probably be available at an early date to the Section officers and the members in general.

In Mr. Warner's opinion, as S.A.E. member who is not a Section member is only half a member. Without direct participation in Section activities, a man cannot take full advantage of what the Society has to offer. A man who is wrapped up in himself usually makes a very small package, Mr. Warner said. There is certainly need for fellowship, human contacts and the rubbing of elbows with our fellowmen to keep us from becoming too stale. Refreshing contact and thrill come from the discussion out of school with men working in your own line. Also, undoubtedly the commercial value of Section membership can be figured out in dollars and cents.

Slide Films Wanted

AT the Transportation Meeting in Toronto, two small tin boxes for films entitled, Part I—The Application of Motor Transport to the Movement of Freight and Passengers, that were used by F. C. Horner, of the General Motors Corp., in connection with his paper read at the joint session with the American Railway Association on Wednesday afternoon, Nov. 13, were lost from the S.A.E. office adjoining the meeting hall in the Royal York Hotel. It will be very much appreciated if anyone who can furnish information that will assist in recovering these films will send it to the Standards Department of the Society at 29 West 39th Street, New York City, as promply as possible, as Mr. Horner is particularly anxious to recover the films.

Papers for William C. Naylor Award

ANNOUNCEMENT of the decision to establish the William C. Naylor Memorial Award was published in the November number of the S.A.E. JOURNAL. Competition for the Award, which consists of a certificate and the initiation fee and one year's dues for a Junior membership in the Society, is National in scope.

It is open only to graduates of recognized colleges offering undergraduate work in aeronautic engineering. The award is to be made each year to the author of the best paper relating to analytical investigation in aerodynamics, aircraft design or construction, or research in fundamental problems of the airplane.

Papers submitted for the award for 1930 must be in the hands of the Detroit Section, S.A.E., Room 2-136, General Motors Building, Detroit, not later than Jan. 15, next. The award is to be bestowed upon the winner at the closing Aeronautic Division meeting of the Detroit Section for the season.

Further information regarding the nature of the papers eligible for the award is given in the November number of the S.A.E. JOURNAL, p. 559.

World Engineering Congress

BARON K. FURUICHI, President of the World Engineering Congress which assembled at the Tokyo Municipal Auditorium last October, acknowledged very courteously the greetings of the Society forwarded for submission at the Congress. The Society secured several papers by prominent members for presentation at the Congress, the purpose of which was to contribute to the progress of engineering science and the enhancement of human welfare.

Semi-Annual Index to The Journal

INCLUDED in this issue of THE JOURNAL as Section 2 is the Index to Vol. XXIV. This index, which covers the issues from January to June inclusive of this year, should have been issued in connection with the July number but its appearance has been delayed for several reasons. Any reader who fails to receive a copy of the Semi-Annual Index as part of this issue of THE JOURNAL is requested to notify the Publication Department of the Society headquarters in New York City, which will mail a copy to him.

The Index to Vol. XXV, covering the issues from January to December inclusive of this year, will be published in connection with an early issue. Indexes to subsequent volumes will, it is expected, be issued regularly as Section 2 of the January and the July issues. This will mark a return to the practice that was followed from June, 1926, to December, 1928.

Life Membership

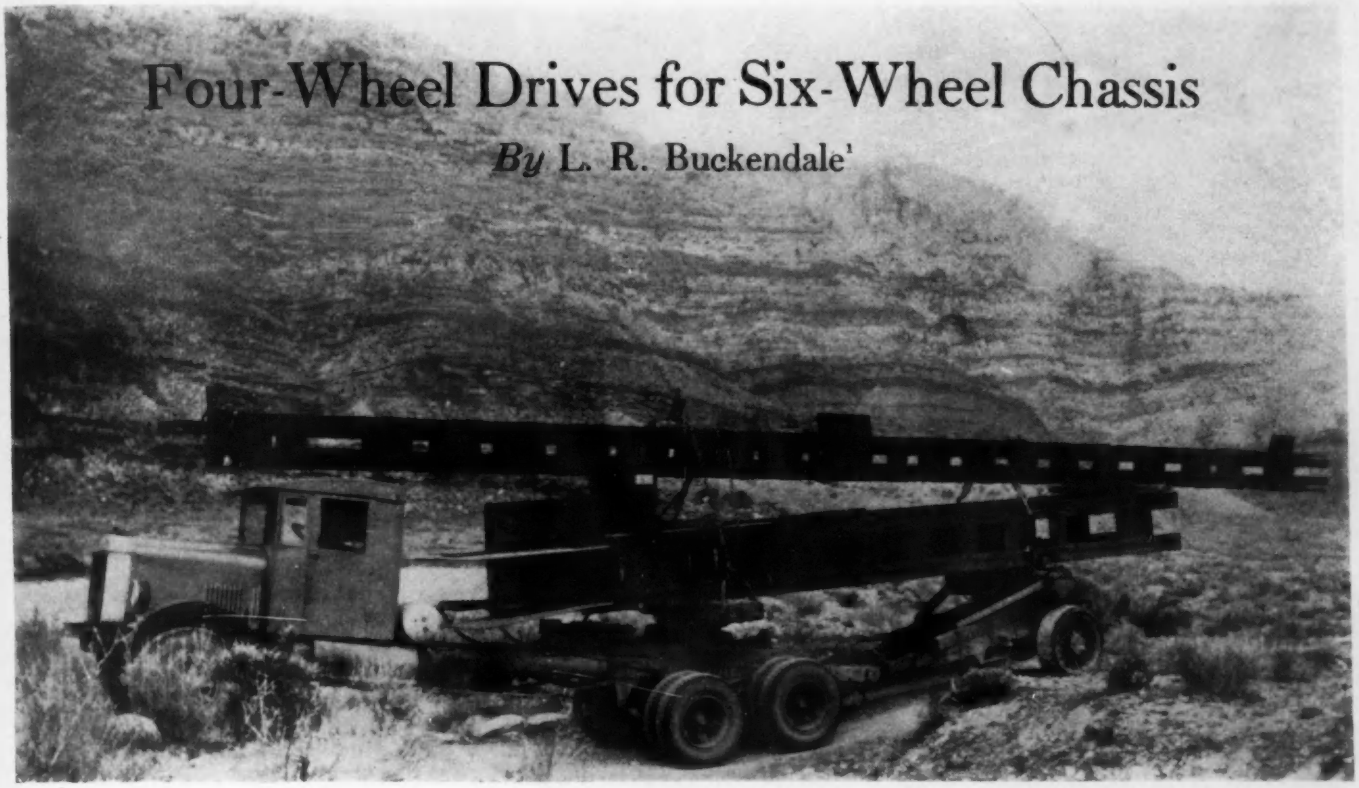
INTEREST has been expressed recently in the cost of Life Membership in the Society. With the approval of the Council, any Member or Associate may purchase a Life Membership in the same grade by payment at one time of an amount stipulated in insurance procedure for an annuity for the life of a person of the age of the applicant for the Life Membership, equal to the annual dues of the grade. A Life Member is of course thereafter not required to pay annual dues, these having been defrayed in one lump without further attention or bother. The cost of Life Membership ranges from $292.34, for a man of 25, to $138.85, for a man of 65.

The figures for the intervening ages are:

Age last Birthday	Amount	Age last Birthday	Amount	Age last Birthday	Amount
26	$289.86	39	$250.55	52	$198.44
27	287.30	40	246.96	53	194.01
28	284.67	41	243.30	54	189.53
29	281.97	42	239.57	55	185.01
30	279.18	43	235.76	56	180.47
31	276.32	44	231.87	57	175.89
32	273.38	45	227.93	58	171.29
33	270.35	46	223.91	59	166.67
34	267.26	47	219.81	60	162.03
35	264.06	48	215.66	61	157.40
36	260.81	49	211.43	62	152.75
37	257.46	50	207.15	63	148.11
38	254.04	51	202.82	64	143.48

Four-Wheel Drives for Six-Wheel Chassis

By L. R. Buckendale[1]



TRANSPORTATION MEETING PAPER — *Illustrated with* PHOTOGRAPHS

MANY interesting problems in design are presented in the application of four-rear-wheel drive to a six-wheel vehicle. As axle design is intimately related to the rest of the chassis construction, the axle builder is concerned with the type of spring mounting, the method of taking the torque, and the distribution of the load.

The author specifies a number of factors that positively must be taken into account and provided for in any construction that is to prove successful. He then shows by photographs and describes a number of rear-end four-wheel-drive constructions that have been built and put into operation. Attention is confined mainly to consideration of the methods of spring suspension to distribute the weight among the wheels and to provide for vertical movement of the four rear wheels relative to one another, means for maintaining the two rear drive-axles parallel to each other and in alignment with the chassis frame, methods of allowing some torsional movement of the drive axles, and ways of avoiding excessive angularity of propeller-shaft universal-joints.

Several designs are shown that are applicable to conventional four-wheel-truck chassis having two-rear-wheel drive and semi-elliptic springs.

The desirability of placing a differential between the two rear driving-axles is in doubt. Tire mileages have been high on six-wheel vehicles having no such differential, and the incorporation of one in the design presents complications and serious difficulties. Two experimental designs showing alternative ways of distributing the power uniformly among the four wheels are illustrated, but the design and production problems are stated not yet to have been mastered.

FOUR-WHEEL rear drive for a six-wheel vehicle presents, from the axle builder's viewpoint, many interesting problems. The conventional four-wheel vehicle driven by a single rear axle is a comparatively simple problem, as years of experience have produced an almost uniform design of spring mounting, and the method of taking the torque through the spring and driving through a radius-rod is practically standard. When the vehicle is driven by two rear axles, the problem is greatly complicated and the axle design is intimately related to the chassis construction. The axle builder is vitally concerned in the type of spring mounting, the method of taking the torque, and the distribution of the load. The following factors must positively be taken into account:

Distribution of Load.—The load must be equally distributed between all four of the rear driving-wheels for a rather large difference in elevation of the road surface upon which the various wheels rest. Practice has shown that the vehicle must be designed to accommodate at least a 10-in. difference in the levels of its wheels.

Flexibility.—The two rear axles must be controlled in such a way that they can move freely as the ground surfaces dictate without introducing binding action or severe bearing loads in the axles and control mechan-

[1] M.S.A.E. — Executive engineer, Timken-Detroit Axle Co., Detroit.

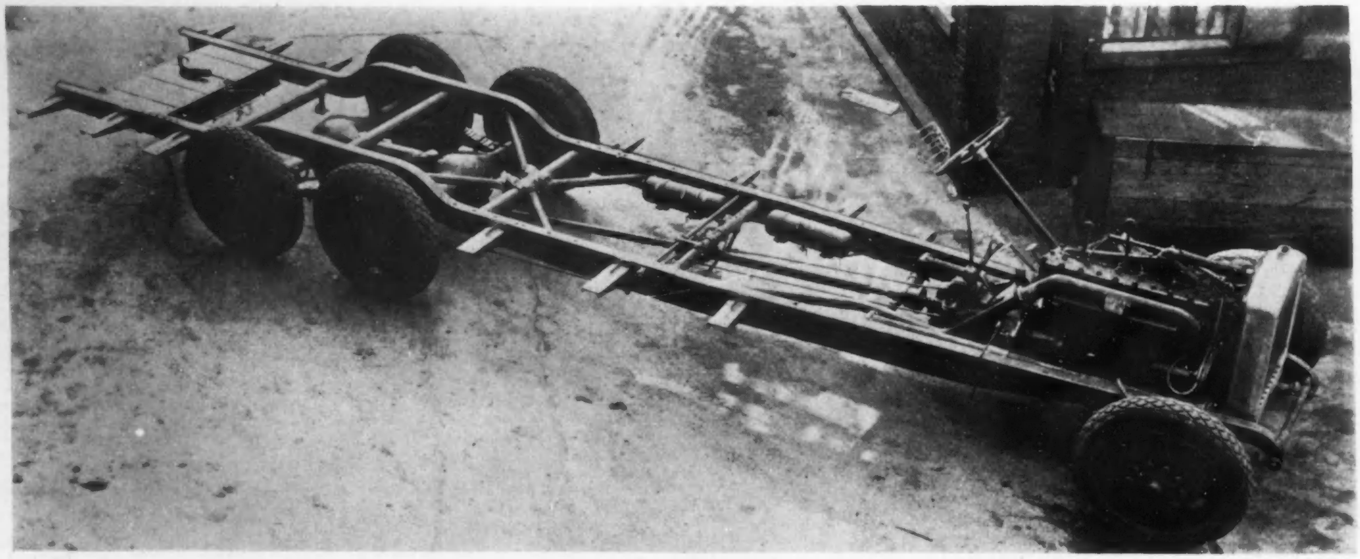


FIG. 1—CHASSIS DESIGN USED CONSIDERABLY UNDER MOTORCOACHES

The Springs Are Inverted and Pivoted at Their Centers on a Bracket Attached to the Frame. The Propeller-Shaft Is Not Subjected to Any Angularity and the Forward Universal-Joint on the Forward Rear Axle Has Considerable Angular Action as the Wheels Rise and Fall

ism. Extreme care must be exercised to prevent high local stresses being set up by this flexure.

Propeller-Shaft Universal-Joint Angles. — These should be carefully considered. No universal-joint should be required to operate at an angle that will set up high operating stresses and loads.

Torsional Flexibility.—The means provided to prevent the axles from rotating when they are subjected to the drive should be of a resilient nature; that is, they must be allowed some torsional flexibility. Experience has demonstrated that this is necessary to assure equal distribution of sudden torque loads and severe torque reactions. If the axle mountings possess some torsional flexibility, the load cannot be suddenly applied to one axle because the axle affected will yield away from such a load, allowing distribution to the other axle. At high speeds, this same flexibility will permit the driving wheels to follow an irregular road surface which might cause the wheels to have varying angular velocities due to the vertical travel. If torsional flex-

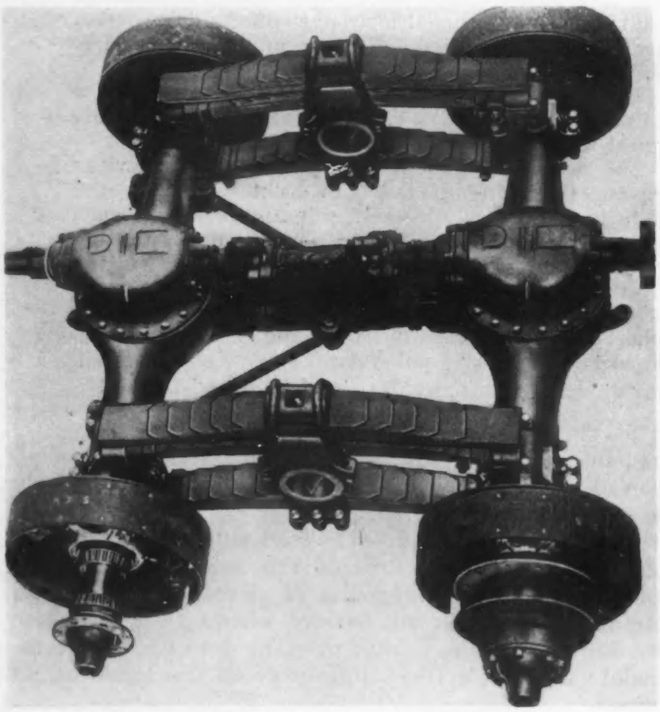


FIG. 2—ASSEMBLY HAVING TWO SPRINGS ON EITHER SIDE, PIVOTED AT THEIR CENTERS

Torque Reaction Is Taken by a Rigid Third Member Connecting the Axle Housings

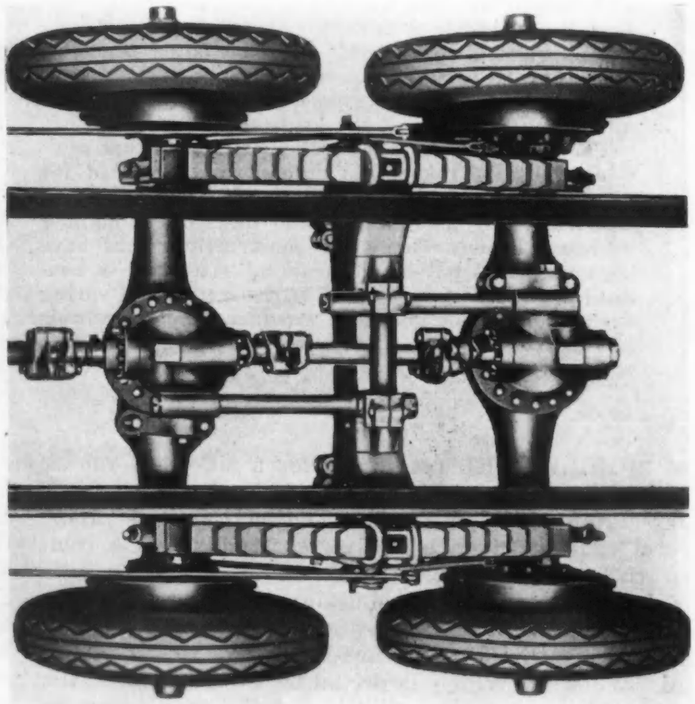


FIG. 3—DESIGN SIMILAR TO THAT IN FIG. 2 BUT WITH THE RIGID THIRD MEMBER REPLACED BY BALL-SEATED TORQUE-RODS THAT ALLOW SOME ROTATIONAL FLEXIBILITY

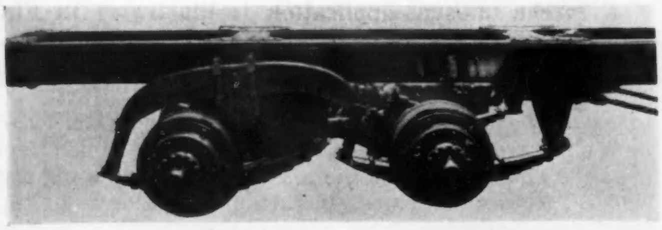


Fig. 4—Unusual Construction Giving Six Points of Loading on the Frame

The Rear Ends of the Forward and Rear Springs Are Connected to an Equalizing Bar Pivoted on the Frame

ibility is provided, the variation in angular velocity is absorbed by slight rolling of the two axles. The required action is similar to that obtained with Hotchkiss drive.

Load Distribution on the Frame.—It is desirable to keep the reaction load distributed on the frame of the vehicle as widely as is possible.

Stability and Alignment.—The design should have inherent stability and provide the maximum resistance to side-sway and lurching. The two driving axles must be aligned so that their wheels track.

Adaptability to Four-Wheel-Chassis Design.—A requirement often arises to alter a conventional four-wheel vehicle to a four-wheel-driven six-wheeler with a minimum of changes from the design in production. If the four-wheel driving unit for the six-wheeler is designed so that it can be put under the existing model with no change in spring mounting, type of radius-rods, and so on, it can readily be appreciated that many advantages will accrue to the manufacturer.

Illustrations are given of certain six-wheel vehicles driven through their two rear axles. These show a variety of designs that have been in production.

Fig. 1 shows a design that has been used considerably for motorcoach service. The springs are of an inverted semi-elliptic type pivoted at the center on brackets attached to the frame. The ends of the springs are mounted on the axles with the eye of the spring below the axle housing. Some designs of this type have incorporated plain spring-shackles and some have included spherical mountings or other means to prevent twisting the spring, the torque of the two axles being taken by two telescoping sleeves. These sleeves maintain the position of the two driving units without allowing any inherent flexibility. The propeller-shaft connecting the driving units is not subjected to any angularity and the forward universal-joint on the forward axle assumes a considerable universal-joint action as the axle rises and falls, pivoting about the spring mounting.

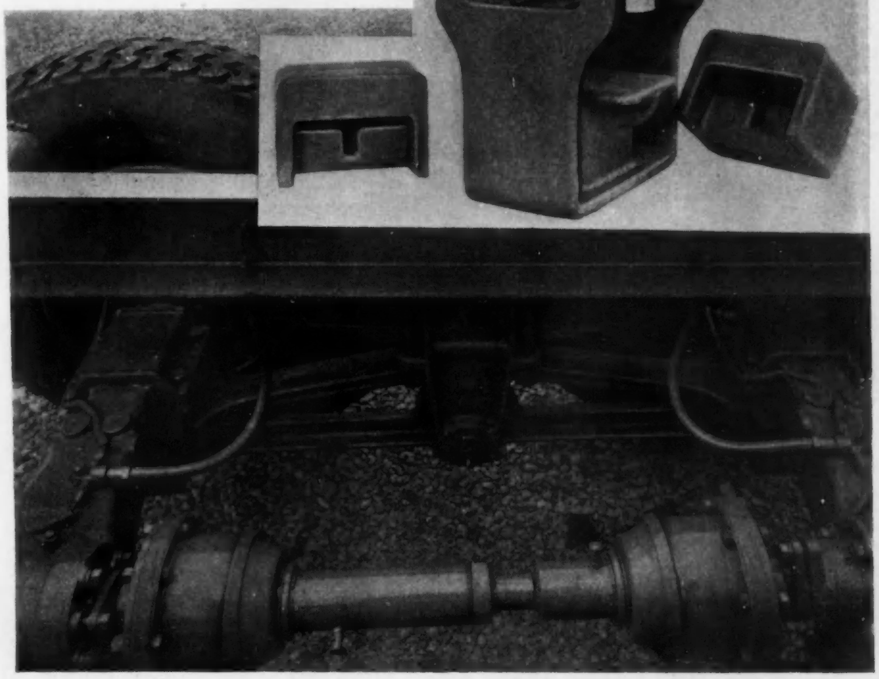


Fig. 5—Design for Vehicles of 11-Tons Gross Capacity

The Ends of the Equalizing Beam under the Semi-Elliptic Spring Are Supported on Rubber Blocks in Stirrups Hung on the Axles. A Stirrup and Its Rubber Blocks Are Shown in Detail Above

In the type of six-wheeler shown in Fig. 2, two semi-elliptic springs are pivoted at their center and mounted on the axle by means of spherical spring-seats. Torque reaction is again taken by means of a rigid third member between the two axle-housings.

Fig. 3 shows the same general type of spring mounting as Fig. 2, but the third member has been replaced by two torque-rods which limit the roll of the two axle-members

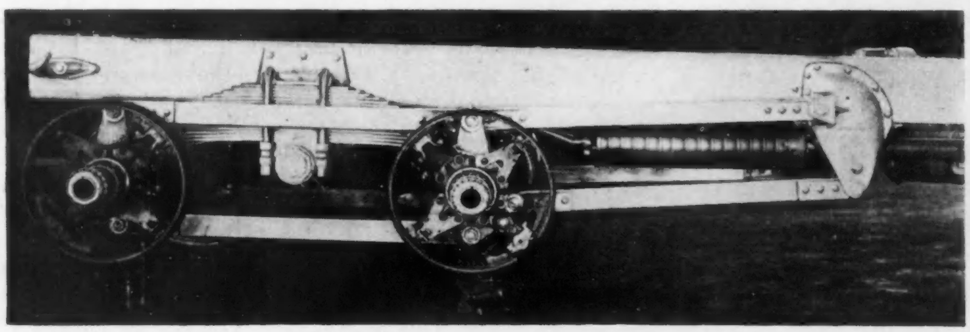


Fig. 6—Parallel-Bar Pantograph Construction for Controlling Axle Motion

The Two Pairs of Parallel Bars on Either Side Are of Flat Stock That Can Twist. They Maintain Parallelism of the Axles and Transmit the Torque to the Frame, but the Design Does Not Provide Torsional Flexibility for the Axles

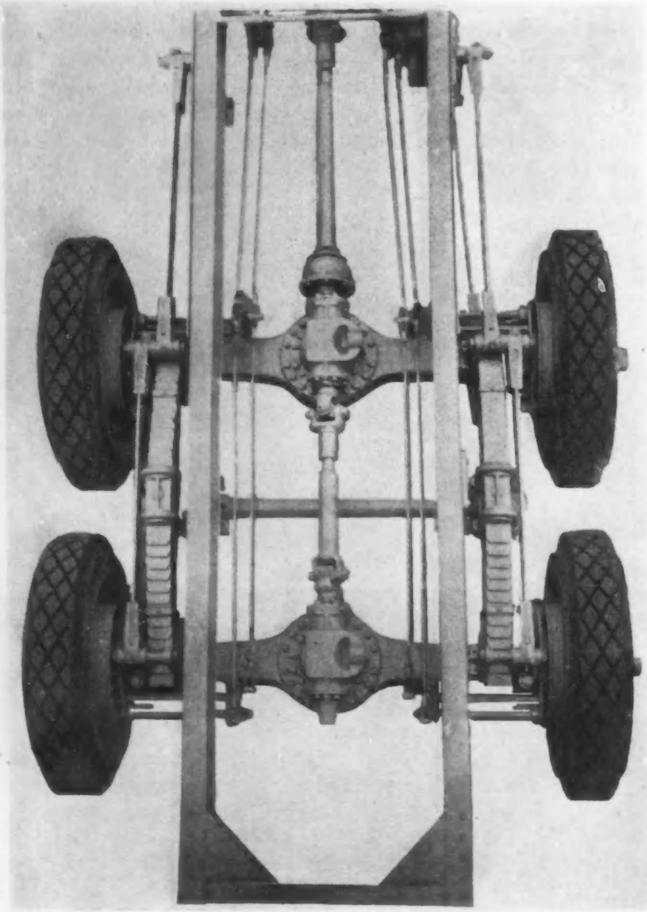


Fig. 7—Top View of Design Shown in Fig. 6

but permit certain rotational flexibility because the ball seats in the ends of these rods are mounted on springs. The torque-rods also introduce a pantograph action so that the driving units remain parallel to each other as they rise and fall and so distribute the angle between the various universal joints.

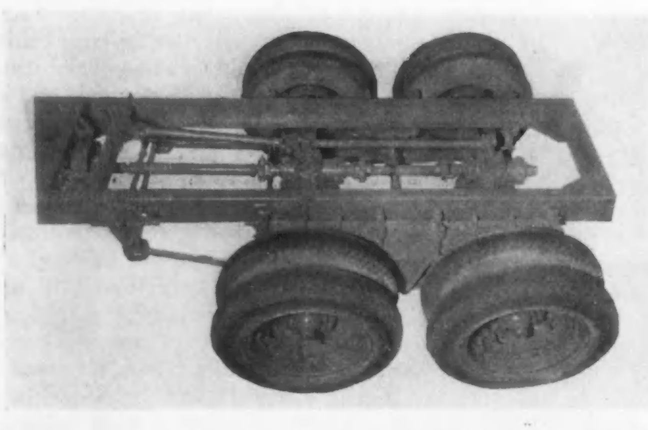


Fig. 8—Design Applicable to Conventional Four-Wheel Chassis Having Single-Rear-Axle Drive

Ends of the Distributing Beams Trunnioned under the Semi-Elliptic Springs Are Attached to the Lower Sides of the Axles by Spherical-Head Pin Mountings. Torque-Rods and Radius-Rods Take the Torsion, Keep the Driving Units Parallel and Distribute the Angularity of the Universal-Joints

A rather unusual application is illustrated in Fig. 4. Each axle carries a semi-elliptic spring, similar in construction to the conventional single-axle mounting. The forward ends of the springs are fastened to the frame as in a Hotchkiss-type drive. The rear ends are shackled to an equalizing bar which permits the rise and fall of the axles without changing the load. The torque member in this construction is of the rigid third-member type. This general construction gives six points of loading on the frame. Action of the rear wheels on a truck of this construction in rough country is shown in the title engraving at the head of this paper.

Another type of six-wheeler which has been made in only relatively small vehicle sizes of a gross capacity of 22,000 lb. maximum is shown in Fig. 5. The springs are of the conventional semi-elliptic type and the load is distributed to the axles by an equalizing beam, which is attached to the axles by means of an ingenious rubber mounting. The beam ends rest

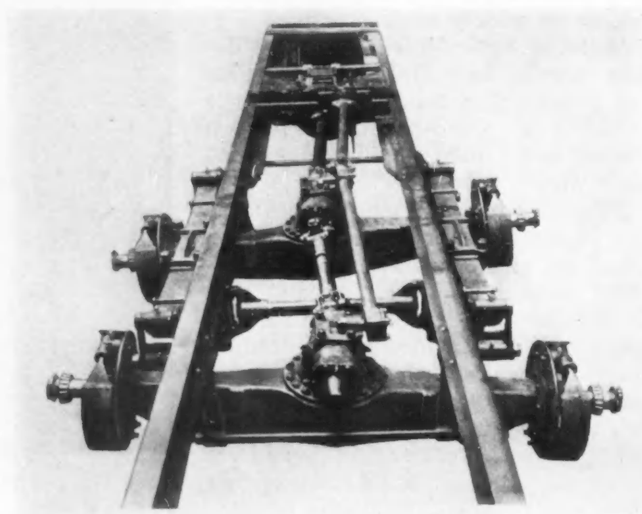


Fig. 9—Rear View of Chassis Illustrated in Fig. 8, Showing Action of Torque and Radius-Rods under Vertical Displacement of One Axle

in stirrups and are supported on rubber cushions below the axles. This gives a pendulum action which tends to keep the axles upright, and torque is further resisted by twisting and compression of the rubber blocks. These rubber blocks and the stirrup are shown in the upper detail view in Fig. 5. This mounting has flexibility as regards loading and torque, and appeals because of its simplicity. However, the capacity of the vehicle in which this suspension can be employed is restricted by the limits of pressure and compression that the rubber blocks can sustain without exceeding the space restrictions in this design.

Parallelism Maintained on Pantograph Principle

In the construction shown in Fig. 6, the spring is an inverted semi-elliptic type trunnioned on the frame and resting on saddles on the axles. Motion of the axles is controlled by a pantograph mechanism consisting of two bars, parallel to each other, joining the brake spiders on each side. These bars are made of flat stock so that they can twist. This design maintains the two driving-units parallel to each other and the torque

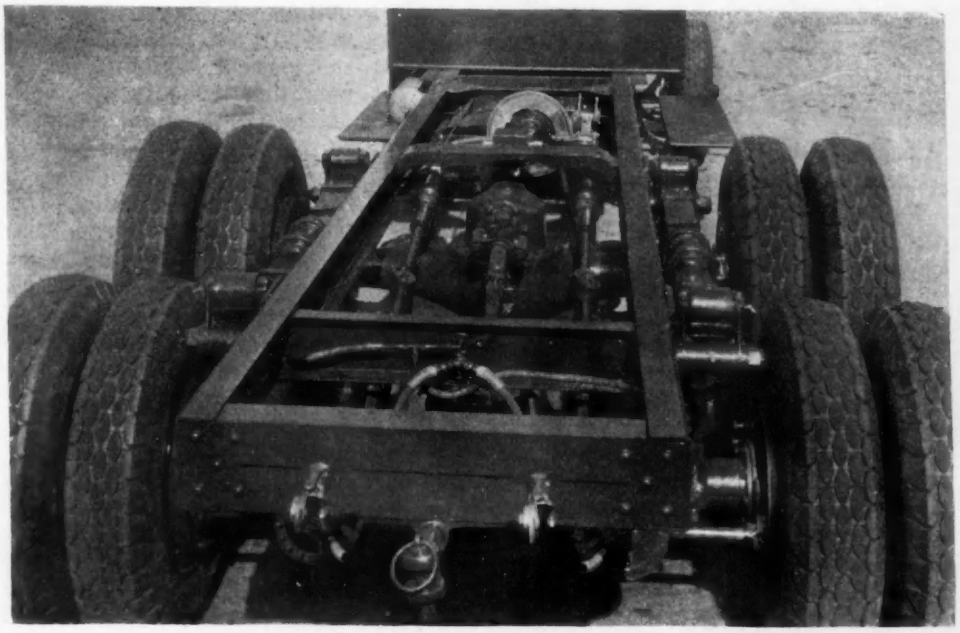


FIG. 10 — FOUR-WHEEL-DRIVE DESIGN APPLICABLE TO ANY CONVENTIONAL CHASSIS HAVING SEMI-ELLIPTIC SPRINGS

The Upper View Shows the Torque-Rods Extending from Arms in the Axle Housings to the Spring Seat and Transmitting the Torque of Both Axles to the Springs. This Construction Is Shown in Larger Detail in the Bottom View. General Flexibility of the Mounting Is Illustrated at the Right, in Which View the Front Wheels of the Chassis Are Much Below the Level of the Four Rear Wheels

is transmitted to the frame by means of two parallel radius-rods, which also are made of flat stock so as to be readily twisted. No torsional flexibility of the axles is provided for by this design. Fig. 7 is a top view of a chassis of this construction.

Another type of six-wheeler, shown in Fig. 8, utilizes the conventional semi-elliptic spring with a distributing beam mounted on a trunnion on its center. The ends of the beam are attached to the axle below the housing by a spherical-head pin-mounting. Torsion is taken by a torque-rod mounted between the two driving units, and from the forward axle to the frame by radius-rods and a centrally mounted torque-rod. This construction gives a pantograph action, keeping the driving units square to the frame and distributing the universal-joint angles. It does not introduce any torsional flexibility because the torque-rods are rigid. It has the advantage that it does not seriously depart from the usual four-wheel-vehicle design and can be applied to almost any conventional four-wheel motor-truck having single-rear-axle drive. Fig. 9 is a rear view showing the torque-rods in greater detail.

Another form of six-wheel construction that can be applied to any vehicle having conventional semi-

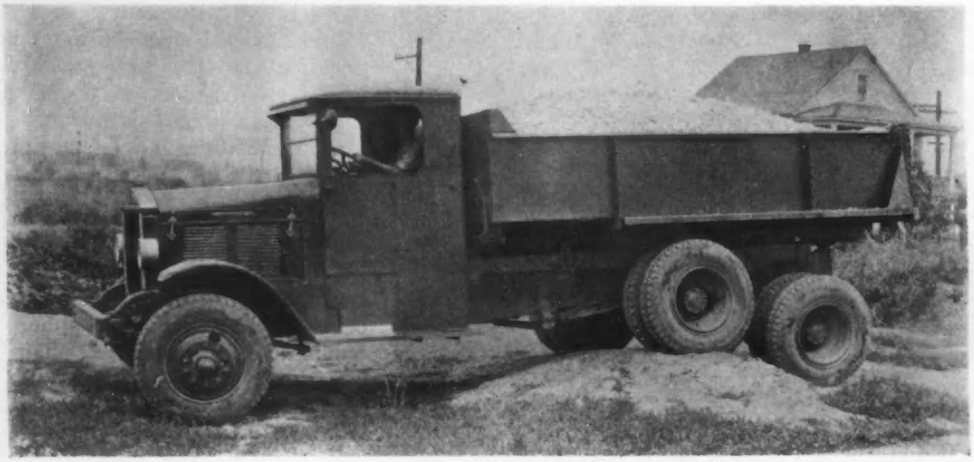


FIG. 11—DEMONSTRATION OF GREAT FLEXIBILITY OF CONSTRUCTION SHOWN IN FIG. 10

elliptic springs is illustrated in Fig. 10. The load is distributed between the two axles by means of a carrying beam mounted on the axles by means of large spherical journal-bearings surrounding the housings. This construction gives perfect freedom of the axles in all directions. The beam is mounted on the spring seat by a large cylindrical journal having considerable length. Torque of the axles is taken by torque-rods connecting extension arms on the axle housing with the spring seat. These transmit the torque of both axles to the springs. This is similar in principle to the way in which the torque is absorbed in the conventional truck having only one rear driving-axle, wherein the rotational action of the axle is absorbed by the spring. Some torsional resiliency is introduced, which is increased by mounting additional springs on the rods on either side of the balls. These rods give a pantograph action which maintains the alignment of the two driving-units paralled with the rest of the vehicle and give approximately equal distribution of angularity among the various universal-joints.

This construction is shown in more detail at the bottom in Fig. 10, and the view at the right illustrates the general flexibility of the mounting. The front wheels of the truck cannot be seen, as they are below the crest of the steep grade, which is a rather unusual position for a truck on paved streets. The flexibility of this unit when mounted under a dump truck is illustrated in Fig. 11.

This construction has virtually all of the desirable elements of flexibility, equal distribution of load on all wheels, equalization of propeller-shaft angles, and torsional flexibility. It has four points of loading on the frame, and it has the additional advantages that it departs very little from conventional practice in frame design and spring mounting and can be used for converting a conventional four-wheel vehicle into a six-wheeler with dual drive with the minimum of change. Such a construction permits driving through the springs, or the springs can be shackled at both ends and drive taken from the distributing beam by a radius-rod attached to the frame.

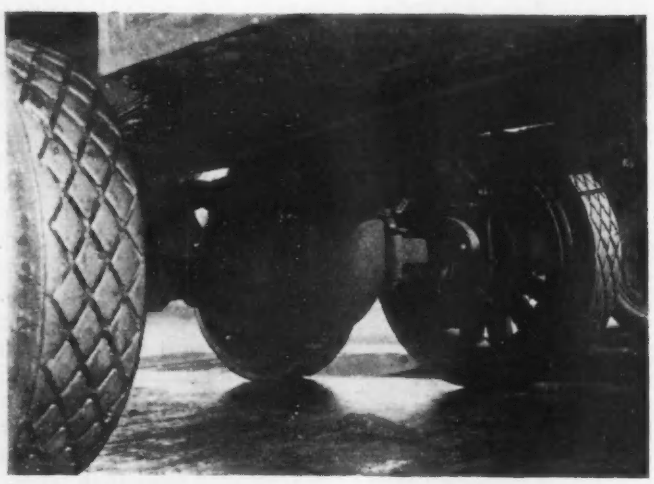


FIG. 12—EXPERIMENTAL DESIGN INCORPORATING A DIFFERENTIAL BETWEEN THE AXLES

Drive from the Engine Is Through a Distributing Differential Mounted as an Integral Part of the Forward Driving-Unit and Is Distributed between the Two Axles by a Gear Train

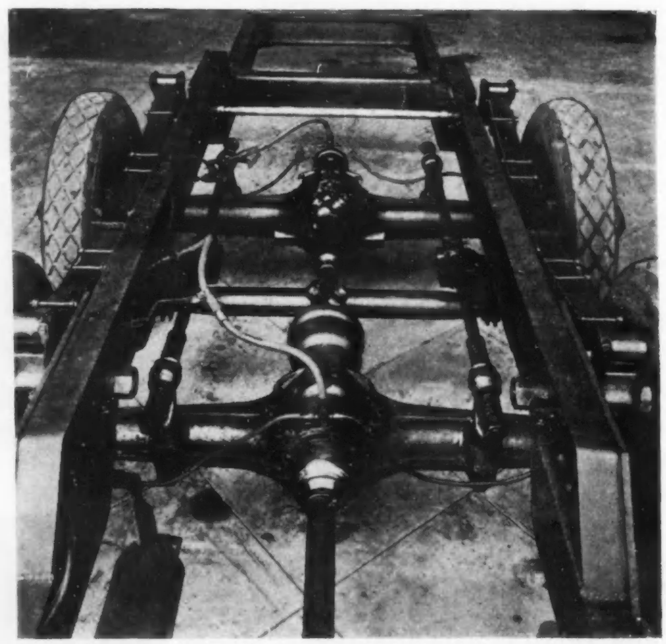


FIG. 13—ANOTHER EXPERIMENTAL DESIGN FOR DISTRIBUTING THE DRIVE TO THE TWO AXLES

A Hollow Worm in the Forward Axle-Housing Allows the Second Propeller-Shaft to Pass Through to the Rear Axle. This Design Involves Problems That Have Not Yet Been Mastered

Experimental Introduction of a Differential

The desirability of placing a differential between the two rear axles has been in doubt, and in virtually all six-wheelers built to date the designers have dispensed with a differential in this location. The addition of a differential between the driving axles

(*Concluded on p.* 603)

Structure of Six-Wheel Vehicles

By A. M. Wolf[1]

Transportation Meeting Paper — *Illustrated with* Photographs and Drawings

RIGID six-wheel vehicles and semi-trailer combinations are classified and described as to load distribution, application of power, arrangement of spring suspension and of tires.

Consideration is given to the desirability of a conventional differential between the two driving axles, and the advantages to be gained by substituting a differential in which the action is limited.

The semi-trailer is said to be useful for specialized services and to compete rarely with the rigid six-wheeler. The automotive industry is said to be following in the steps of railway engineers in providing more wheels for greater loads.

At the close of the paper is given a bibliography of S.A.E papers and general periodical literature referring to six-wheel vehicles.

WHEN the number of elements in any unit is increased, be they cylinders or wheels, the possible number of permutations is enlarged. This is true of the six-wheel vehicle, although most of us may think of it only in terms of the two-driving-axle unit that some of the parts makers are furnishing. In pointing out the various types of construction, some recently introduced, I trust that I shall stimulate interest and discussion so that no meritorious arrangement shall be overlooked.

The first commercial utilization of six wheels was in the semi-trailer combination, which is a single instrument insofar as the load is concerned, as neither tractor nor trailer alone could transport the load. This is purely a technical viewpoint and should not be confused with the legal interpretation of the majority of the States concerning gross weight, as found in a survey made by the Motor-Vehicle Conference Committee, that semi-trailers or trailers attached to trucks or tractors are regarded as separate units.

Referring to Fig. 1, the conventional semi-trailer is diagrammatically indicated at *A* and might be regarded as a unit with an articulated frame. The rear wheels of the tractor, which do the driving, are represented by a heavy circle. The need for a pivotal connection between trailer and tractor, to allow all the wheels to maintain contact with the ground, was early recognized. The majority of six-wheel trucks also provide for such equalization, though in a different way. Application of power to the four tractor wheels is indicated at *B*. A vehicle incorporating this scheme, which is shown in Fig. 2, is interesting because of its diversified uses: to flush streets, empty flooded basements, clean sewer inlets, fight fires, sprinkle dirt roads, oil unpaved roads, spray trees, grade roads, plow snow and to haul garbage trailers or regular commercial trailers.

Rigid Six-Wheelers

The distinction between the semi-trailer and the six-wheel truck is well expressed in England by referring to the latter as the rigid six-wheeler. The early attempts at this type of vehicle were more concerned with load distribution than with traction. At *C*, in Fig. 1, we find a conventional rear-axle ahead of a dead axle. Conversion units to make a four-wheel truck into a six-wheeler, like that in Fig. 3, come under this classification. The two axles usually are connected by an equalizing beam, as will be portrayed later. The equalizer is sometimes eccentrated, to throw more weight on the driving axle than on the dead axle. In one instance the loading of the axles was worked out as follows: front,

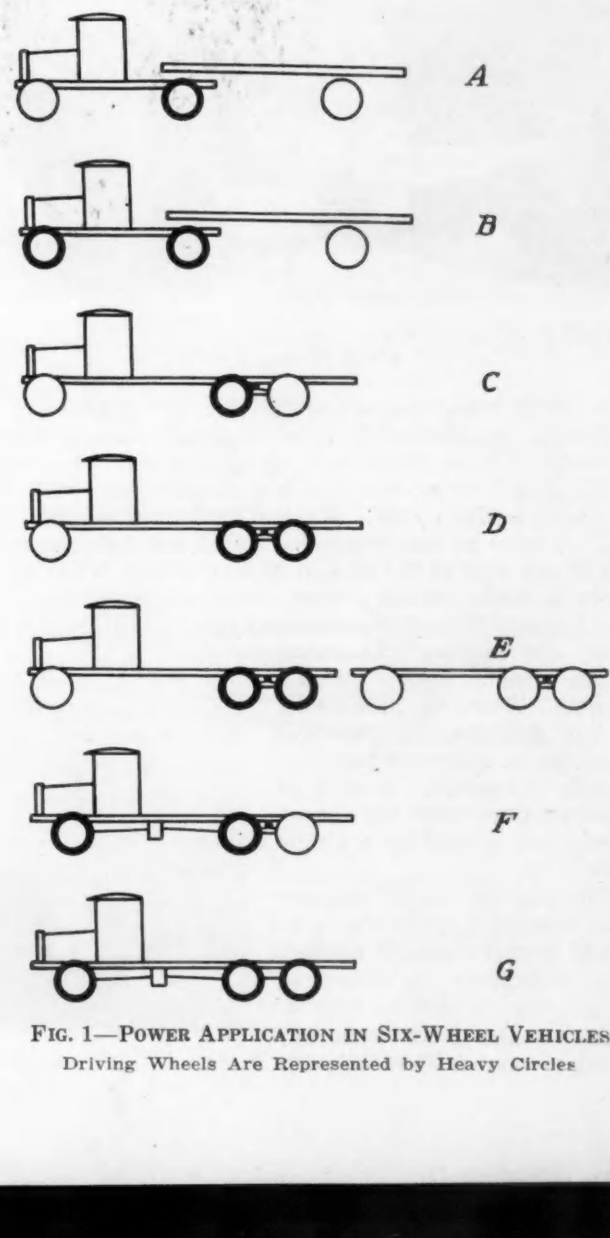


Fig. 1—Power Application in Six-Wheel Vehicles
Driving Wheels Are Represented by Heavy Circles

[1] M.S.A.E.—Automotive consulting engineer, Newark, N. J.

Fig. 2—A Multiple-Purpose Four-Wheel-Drive Tractor

25 per cent; driving, 42 per cent; and rear, 33 per cent. As with semi-trailers, brakes were applied to the center and rear axles. To gain traction, both axles have now become driving axles, as indicated at *D*, in Fig. 1, which is the form most popular today.

Small-diameter rims have aggravated the brake problem, but suitable braking performance is obtainable on the six-wheeler by placing four brakes inside

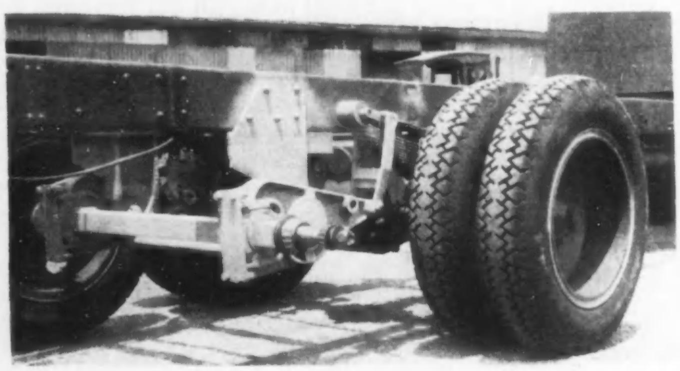


Fig. 3—Utility Unit for Adding Two Wheels to a Four-Wheel Truck

the 20-in. rims, in place of the two only, which are not effective on the single axles of large-capacity trucks. Greater frame width and spring spread are possible with single tires on a double rear-axle than with dual tires on a single axle. We find that the dual tires and the springs at the two sides sometimes take as much as 65 per cent of the maximum legal width, when allowance is made for the proper tire spacing and clearance for chains. Therefore, six-wheel design has aided those who are seeking the maximum frame and spring spread. While the increasing use of dual tires on six-wheel vehicles is cutting down this width somewhat, it still is greater than with the larger dual tires needed on a single axle.

Because of the advantageous weight distribution, six-wheel construction is applied also to trailers, as shown at *E*, in Fig. 1, and in Fig. 4. Double axles have been applied to semi-trailers as well. Future developments with gasoline-electric tractors no doubt will bring power application to trailer wheels, and a further subdivision of the *E* classification will result.

Four-wheel drive truck design has been expanded into six-wheel construction by the addition of another rear-axle, as indicated at *F* and *G*, in Fig. 1. The former method is used in the FWD chassis shown in Fig. 5, while the latter is incorporated in the Coleman truck seen in Fig. 6.

Reverting to the popular construction involving a bogie truck, illustrated at *D* in Fig. 1, various classifications can be made according to the method of power transmission. The prevailing transmission, in which a worm or hypoid-pinion shaft of the forward driving axle is extended through the housing and drives the rear axle through a short universal-jointed shaft, is indicated at *A*, in Fig. 7. A double-reduction axle with the spur-gear reduction ahead of the bevel pinion also lends itself to this combination and has, I believe, been experimented with at Camp Holabird, Md.

Inter-Axle Differential

The direct connection between the two worms or pinions raises the question of the desirability of a differential between the two axles. A limited amount of relative movement between the axles is allowed in the Timken construction. In a perfectly rigid torque-reaction hook-up, one axle will fight the other when one wheel passes over an obstruction. The resiliency of the parts, especially of the shafts, is called into play, and possibly a certain amount of tire slippage occurs under severe conditions. We owe much to the heat-treating departments, for flexibility with safe recovery will cover a multitude of discrepancies.

A differential would seem desirable, at first thought, to cause each axle and wheel to carry its share of the torque and to guard against the fight resulting from one set of tires being worn or inflated more than the other. Inspection of standing heights will guard against this condition, and compensation can be made by adjusting the tire inflation. However, this ideal of four-wheel traction exists only under normal conditions. Should one wheel spin, because of insufficient traction or

Fig. 4—Six-Wheel Tractor and Utility Six-Wheel Trailer

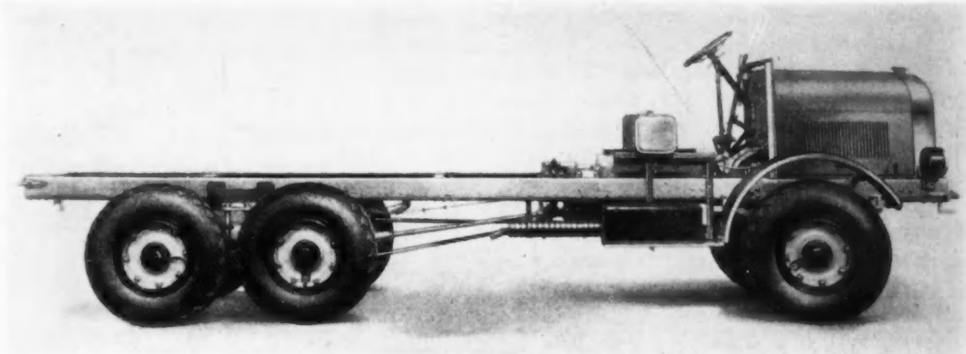


FIG. 5—FWD SIX-WHEEL CHASSIS

bouncing, the other three wheels would become inoperative if the ordinary type of differential were used. In rough going, it would be impossible for each wheel to have continuous traction. Wheel spin would be double that of the single-axle wheel, because of the extra differential. The shock and tire wear, when the wheel again took hold, would be exceptionally severe.

It will be seen that an inter-axle differential of the conventional type is not desirable. Without it, should one wheel have an opportunity to slip, the other axle

FIG. 6—REAR PORTION OF COLEMAN SIX-WHEEL CHASSIS

would prevent it from speeding up faster than its mate. Under such conditions, one axle is ineffective in driving, and the other axle takes the full torque. Ordinarily, this condition is only momentary, but when off the highway—and no doubt many look on the six-wheeler as a solution to rough going—one axle is taking the full torque load a great part of the time. It therefore seems obvious that two axles, each having one-half the torque capacity of the one large axle that a bogie unit replaces, are insufficiently strong. For cross-country work, each axle should be capable of carrying the full torque. The chances of skidding are lessened by omitting the differential between the axles.

Use of Modified Differential

The new Mack construction, in which the shaft back of the transmission drives the forward jackshaft by means of hypoid gearing, is shown in Figs. 8 and 9. The rearward extension transmits power to the rear jackshaft. No differential was placed between the jackshafts in the original design, shown in Fig. 8. Subsequently, the unit shown in Fig. 9 was substituted for the forward jackshaft. It will be noted that the drive is taken to a Krohn differential, from which power is conveyed to the forward pinion by means of a sleeve, and rearwardly through the tail-stub shown. Such an arrangement could be incorporated in the *A* type, Fig. 7, by driving through a hollow worm or pinion to or from the differential unit. The previously mentioned shortcomings of the standard differential do not hold with a special type of differential or differential substitute that will not allow spinning of the wheel or unit having insufficient traction; and the ideal of four-wheel traction is possible, depending upon the efficiency, durability and proper functioning of the compensating device.

It is interesting to note the elimination of keys in some of the vital mountings of the Mack design, a jaw-clutch type of construction being substituted. The spherical spring-ends are of interest, as is also the auxiliary cross-spring above each axle.

Torque Reactions

Attention is called to the four radius-rods in the Mack design whereby each drive has its individual means of torque reaction, with its resultant thrusts. This differs from constructions in which the torque reaction is wholly self-contained within a bogie unit. The weight on the bogie is not increased by the driving torque as is the rear-axle load of the four-wheel rear-driven vehicle, in which the torque reaction augments the static load on the rear axle and lessens that on the front axle. All reactions are self-contained in the bogie unit, and the pivotal connection would nullify any torque transmission if it did exist. The reactions of the two axles result in a shifting of the weight from

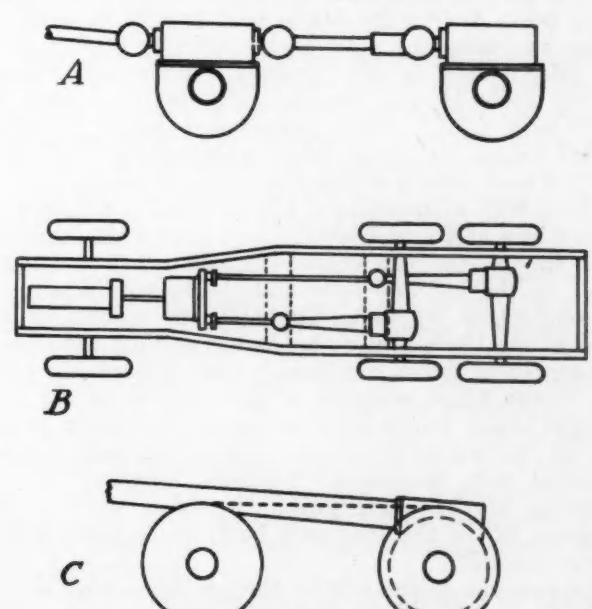


FIG. 7—ARRANGEMENTS OF POWER TRANSMISSION FOR SIX-WHEEL VEHICLES

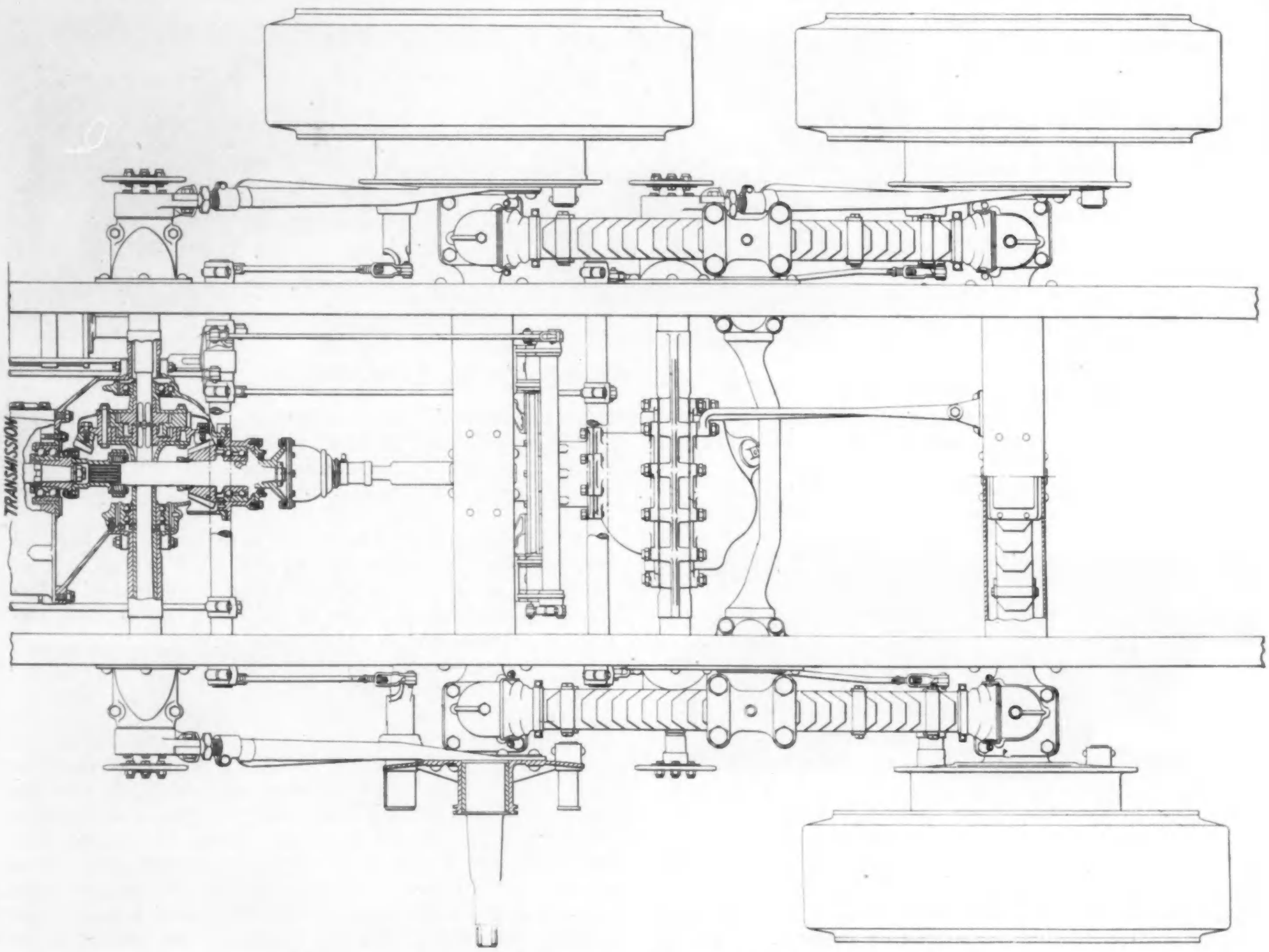


FIG. 8—CHAIN-DRIVE CONSTRUCTION OF MACK SIX-WHEEL CHASSIS

the forward driving axle to the rear axle. The equalizing beam divides the static load equally between the axles, assuming the pivot to be centrally located, as is the rule. Under driving torque, the downward pressure of the forward axle becomes less than one-half the static-load value. With independent torque reactions to the frame, as in the Mack construction, the static load on each axle is augmented when driving.

Many who witnessed the hill or ramp-climbing demonstrations at Camp Holabird last June were surprised that one of the six-wheelers would reach a certain point on the hill and then slide backward in spite of its four-wheel traction. The shift in weight on the axles of the bogie unit under severe driving conditions, augmented by frame and load weight through the pivot due to the tilted position of the vehicle on the hill, brought about an unstable or incipient rearing condition of the bogie; therefore traction on the rearmost axle was lost, because of unsteady torque from the jockeying of the bogie unit. If sliding started, the "digging in" of the rear axle held the forward bogie-axle in the air.

The extreme angularity of the universal-joint ahead of the forward axle was evident in the same tests. The worm shafts are maintained parallel to the frame and to each other, and therefore would not suffer from periodic speed fluctuations; but the relative rise and fall of the forward joint is considerable, and most vehicles do not provide sufficient propeller-shaft length between the transmission and the bogie unit to make the resulting angle as little as it might be.

Uncommon Constructions

Büssing uses two independently driven axles, the schematic layout being as shown at *B*, in Fig. 7. Power is transmitted through a gear train immediately behind the transmission, and the torque reaction is taken by individual torque-tubes having spherical ends supported by frame cross-members. A "breathing" action, similar to the yielding in the Timken unit, can be obtained by centrally pivoting the gearcase on the transmission and restraining its movement by spring action, possibly with a hydraulic dashpot or shock-absorber. The Ford conversion unit made by the Dual Duty Co. is indicated at *C*, in Fig. 7. The rear axle of the original truck remains unchanged, a dead axle is placed ahead of it, and the Ford cantilever spring is utilized between the two axles. A chain drive connects the wheels. In the *C* arrangement, the two wheels at each side are positively connected. The resulting relationship is different from the *A* arrangement, as slippage of one wheel in *A* would make the opposite wheel

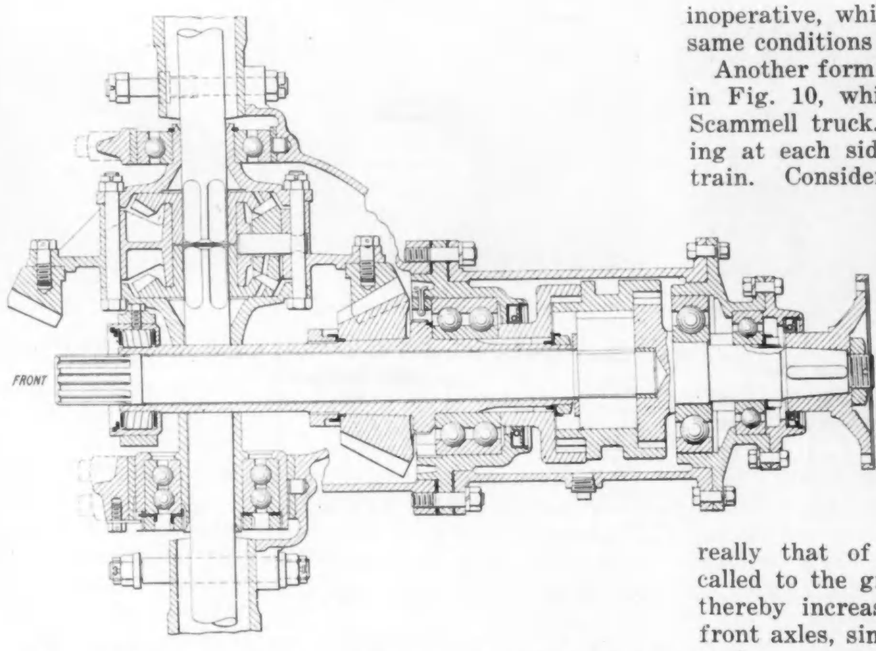


FIG. 9—MACK CONSTRUCTION WITH SPECIAL DIFFERENTIAL

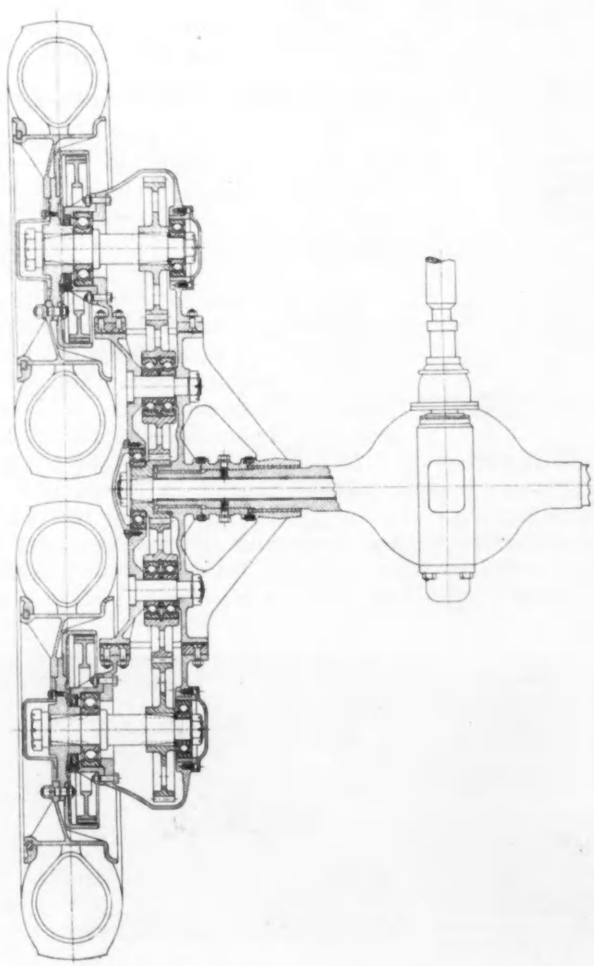


FIG. 10—SCAMMELL DESIGN WITH FOUR WHEELS ON ONE AXLE

inoperative, while three wheels would drive under the same conditions in *C*.

Another form of this basic arrangement is illustrated in Fig. 10, which shows the rear-axle layout of the Scammell truck. A gearcase pivots on the axle housing at each side, and drive is established by a gear train. Considerable latitude of movement about the housing is possible without the interjection of high universal-joint angularities. A creeper track could be applied with this construction, because the wheel centers are maintained constant. The Christie eight-wheel drive, shown in Fig. 11, also utilizes a pivotally suspended gearcase with gear train, the wheels being mounted on each side thereof and balancing the overhang existing in the Scammell construction. While eight wheels are used, the effect is really that of four well-spaced duals. Attention is called to the grooving of the tires in opposite helices, thereby increasing the wheel grip. Centrally pivoted front axles, similar to that of a farm tractor but with spring suspension, are used in both the Scammel and Christie trucks, making the vehicles of the three-point-suspension type.

Suspension Arrangements

Fig. 12 shows diagrammatically various suspension means that have been used or proposed. In the *A* and *B* types, no attempt is made to compensate for uneven terrain. Experience has shown this at-first-glance incorrect arrangement to have real virtues. The equalizer beam serves ideally for ordinary work, but it is essential to provide stops or straps to limit the movement in severe service. In going over an obstacle, one axle or its beam-end will come against a stop and the other axle will ride free from the ground. In backing up to an excavation, if the rearmost axle is allowed to run clear of the ground and hang in mid-air, the stop or strap will catch it and throw the full load on the other axle.

One axle will come off the ground a little sooner in the *A* or *B* type than in the *J* or *K* type with stops; it is only a question of the time element between the two; and the simpler construction results in less severe punishment all round for cross-country work, in which one wheel or axle is certain to be off the ground part of the time. The question arises whether the flexibility is sufficient to take care of what unevenness might occur on good ground. Load is not transferred from one axle to the other in this construction, because the independent springs take the torque reactions.

When one axle is entirely off the ground, the other naturally must support the full weight; hence, for hard going, each axle should be sufficiently strong to be able to do this. The same condition has been mentioned regarding torque capacity. It is safe to say that two 2½-ton axles cannot be substituted for one 5-ton axle, and, except under ideal conditions, be subjected to the same static and torque loads without difficulty ensuing.

Type *B* mounting, of Fig. 12, is used on the chassis shown in Fig. 6. Type *C* is incorporated in the Versare construction shown in Fig. 13. The short lever assumes a considerable angle in rough work, but it is

Fig. 11—Christie Chassis with Eight-Wheel Drive
The Basic Construction Is Similar to That of Fig. 10, with Wheels Each Side of the Gearcase instead of on One Side Only

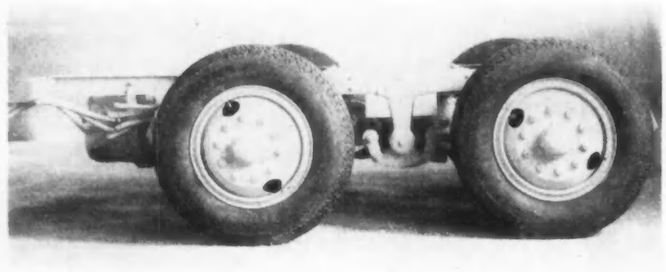


Fig. 13—Versare Bogie Truck, with Equalizing Beam between Springs

suitable for motorcoach service on good roads. Types *E* and *F* are combinations of *C* and *K* and *C* and *D*, respectively. In *G* and *H*, bell-cranks and connecting-rods replace the levers of *C* and *D*. The Paris Omnibus Co's. original six-wheeler had a trailer axle behind the driving axle, and the two were equalized by means of

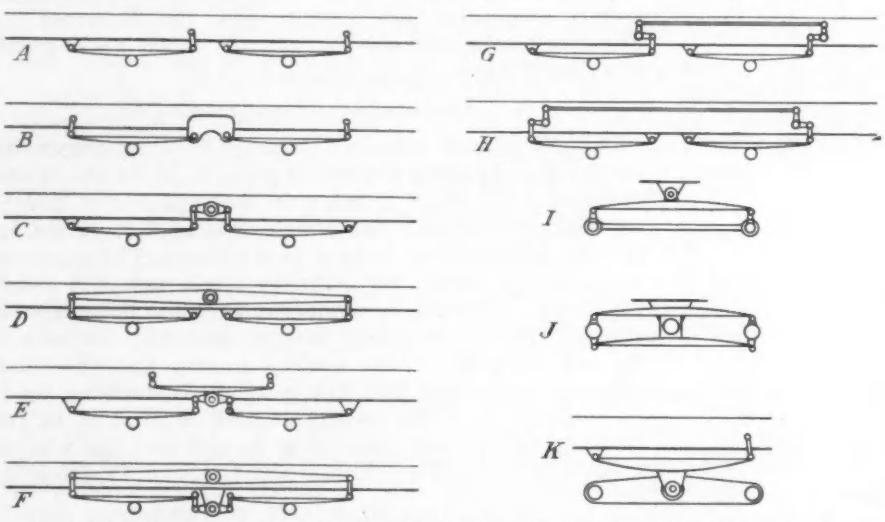


Fig. 12—Spring-Suspension Arrangements of Six-Wheel Vehicles

bell-crank levers. Type *I* was used by Renault on his trans-Sahara vehicle. Types *J* and *K* predominate to-day. The Scammell construction approaches the *K* type, except that the equalizing beams between the axles are replaced by the gearcases between the wheels.

Tire arrangements in six-wheelers provide numerous combinations. Fig. 14 indicates pneumatic-tire arrangements that have been used, with a typical vehicle adjacent to each diagram. The dual front tires in *D* and *E* are used with front-drive axles. The steering pivot and the center-line of the inner wheel coincide; therefore, the lever arm on the outer tire is equal to the tire spacing, and steering is not too great an effort, as it would be if both wheels were to overhang the pivot axis. Should dual front tires prove efficacious, the steering pivot will be brought midway between the rim centers.

Six-Wheeler Versus Semi-Trailer

The increased carrying capacity of the six-wheeler over the four-wheeler raises the question as to how far this will combat the argument of the semi-trailer contingent on the score of greater loading. Where permissible weights are governed by the tire width or sectional diameter, the semi-trailer no longer has its former advantage as to legal restrictions, since six wheels and tires are reckoned upon in either case. Unfortunately, a few States maintain a single maximum allowable weight, regardless of whether the vehicle has four or more wheels. In view of the numerous authoritative and conclusive proofs regarding the superior distribution of road loading and the lessened destruction resulting from a six-wheel vehicle, it is

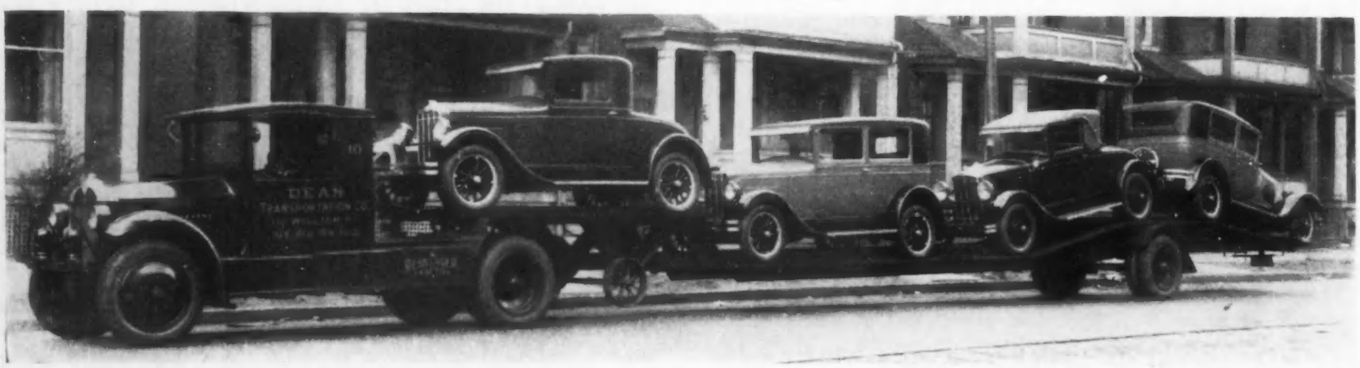


Fig. 15—Rehberger Tractor and Semi-Trailer

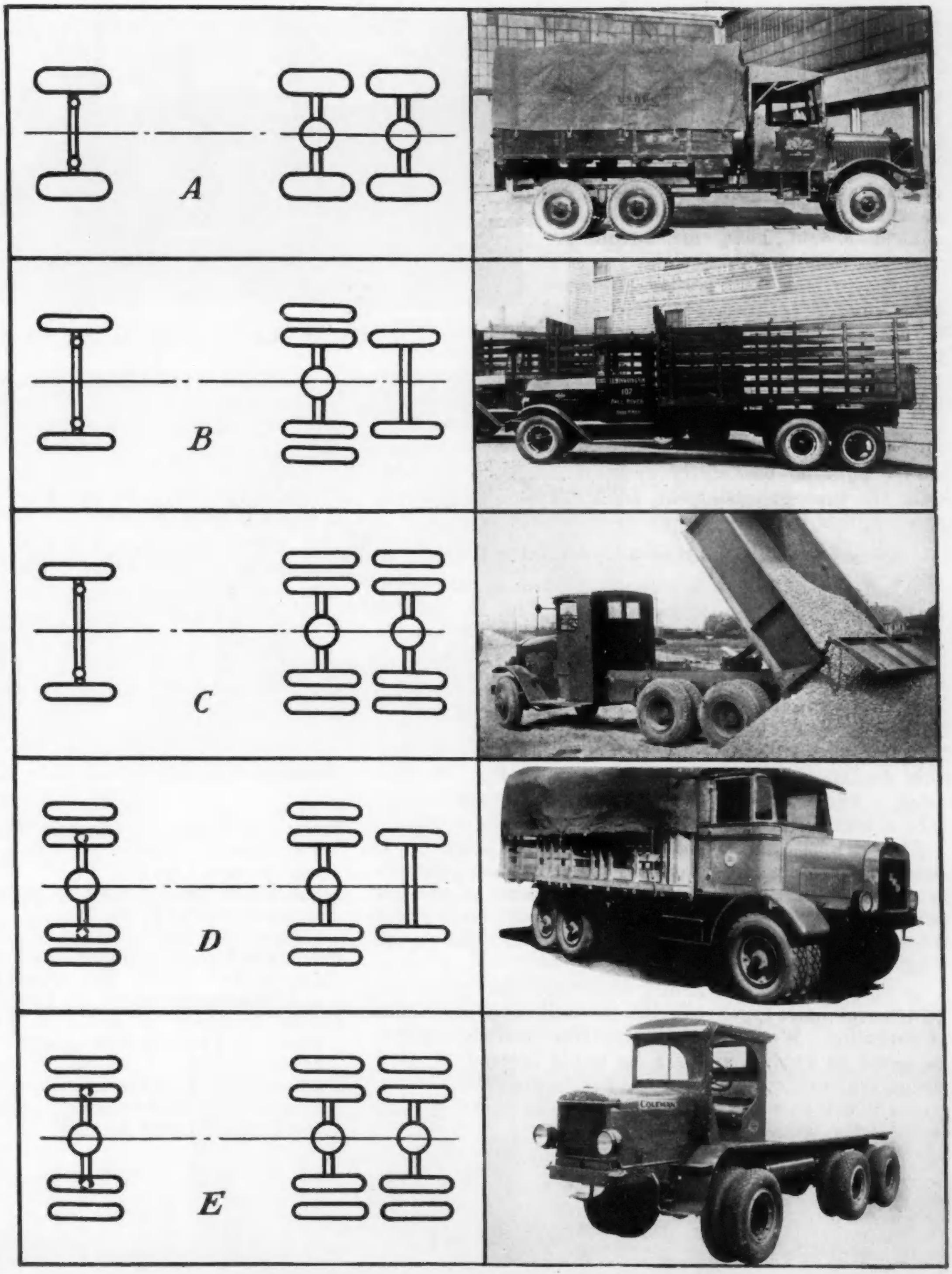


FIG. 14—TIRE COMBINATIONS ON SIX-WHEEL VEHICLES

Vehicles Shown Opposite the Various Diagrams Are as Follows: *A*, Model B Army Truck Redesigned for Bogie Unit; *B*, American-LaFrance Truck with Utility Attachment; *C*, Diamond-T Truck with Wood Mechanical Hoist; *D*, FWD Truck for Bell Telephone Co.; *E*, Coleman Truck with Platform Body

ardently hoped that these few States will follow the modern and correct viewpoint of the majority.

Let us consider the actual weight distribution among the three axles of the six-wheeler and the tractor-semi-trailer unit. For the six-wheeler we will assume a chassis weighing 14,000 lb. and a load of 20,000 lb. and allow 3000 lb. for the body. With the semi-trailer, having a weight of 5400 lb. and assuming the same load and body weights, we will utilize a tractor weighing 7940 lb. The weight distribution of the semi-trailer was considered as 45 per cent on the fifth wheel, and 55 per cent on the rear axle. Many trailers throw more weight on the rear axle, and that would slightly equalize the figures for the semi-trailer. The weights will be distributed on the axles as shown in Table 1.

It will be seen that the axle loadings are almost alike in the two types; however, the semi-trailer is at a disadvantage in the effect of the load distribution on traction, in the ratio of 17,080 to 31,570. Field conditions will control the importance of tractive ability. The six-wheeler is the shorter vehicle and requires less space on the highway.

Trailers have often been sold on the basis of utilizing the excess power available in the engine, with the resultant fuel economy per ton-mile, assuming that driving in gear will not wipe out the level-road economy. The tractor has usually been equipped with an engine of lower power-output than that of a truck designed to carry the same load. There is no reason why a six-wheeler cannot be built with the same power-load ratio as the semi-trailer combination and operate at the same economy. A certain amount of work can be accomplished with a given amount of energy, regardless of

TABLE 1—DISTRIBUTION OF WEIGHT ON THREE AXLES, POUNDS

	Front Axle	Center Axle	Rear Axle	Total
Six-Wheeler	5,430	15,785	15,785	37,000
Tractor-Semi-Trailer	4,140	17,080[a]	15,620	36,840

[a] Includes 500 lb. for fifth-wheel.

how it is made to do the work; provided the energy is transmitted efficiently and not wasted. Neither of the two types has any outstanding handicap; therefore, the power used in either case depends on the speeds that must be maintained and the topography of the country traversed, as it relates to gearshifting. Neither vehicle should have an advantage over the other on this score.

However, the semi-trailer has certain inherent advantages that place it in a class by itself, freed from competition with any other possible vehicle construction. Nothing can replace the detachable unit which can be loaded or unloaded while another is being transported by the tractor. While detachable bodies are a possibility, the auxiliary equipment necessary would be too costly and complicated, compared with the present equipment, so that this could be considered only in a very large fleet.

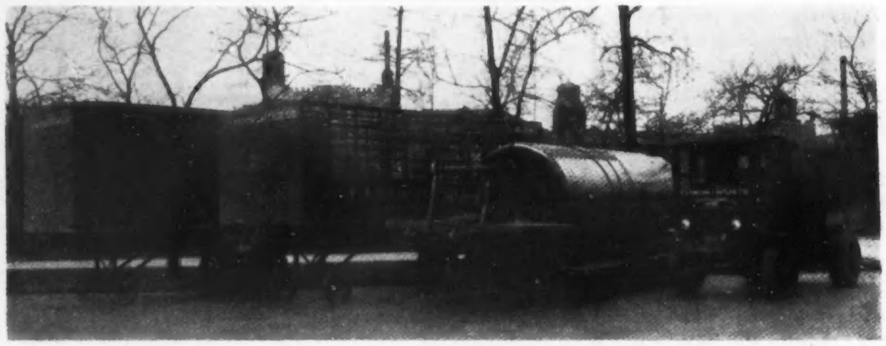


FIG. 16—LAPEER SEMI-TRAILERS WITH TRACTOR

Semi-Trailer Has a Special Field

When special bodies are needed or the length of the loading platform is exceptional, as in Fig. 15, nothing can replace the semi-trailer. Awkward loads can be maneuvered better with an articulated vehicle. In fleet operation, an extra tractor in reserve provides a handier spare unit than does a powerplant, which would involve tying up the vehicle while it is being installed. The tractor and semi-trailer provide unique transportation facilities for diversified service, as Fig. 16 indicates. The use of a dolly, to convert a semi-trailer into a trailer, opens up possibilities of road trains.

The stepped tank semi-trailer, seen in Fig. 17, is becoming very popular for city use. Its performance is very satisfactory and economical, because of the low power-factor required under these conditions. Some interesting developments of the year are shown in Figs. 18 and 19.

In conclusion, I am firmly convinced that six-wheel vehicles of both types will increasingly find new fields of operation. We are simply rewriting railroad history, in terms of rubber and air on roads instead of steel wheels on steel rails. As rail-equipment weights increased, the number of wheels was increased to distribute the load.

It will be seen that rigid six-wheelers and semi-trailers are competitive only in a narrow field; as the semi-trailer caters to a distinctive field of transportation.

I have tried to emphasize that each particular service must be carefully weighed to choose the detailed construction that will best meet the requirements. We are all interested primarily in furnishing transportation efficiently and economically. If that is accomplished, it will show that torque reactions, load capacities, number of wheels or axles and all the other technical matters have been harmonized into the complete design.

Those who are vitally interested in six-wheelers will find the following bibliography to cover the subject quite thoroughly:

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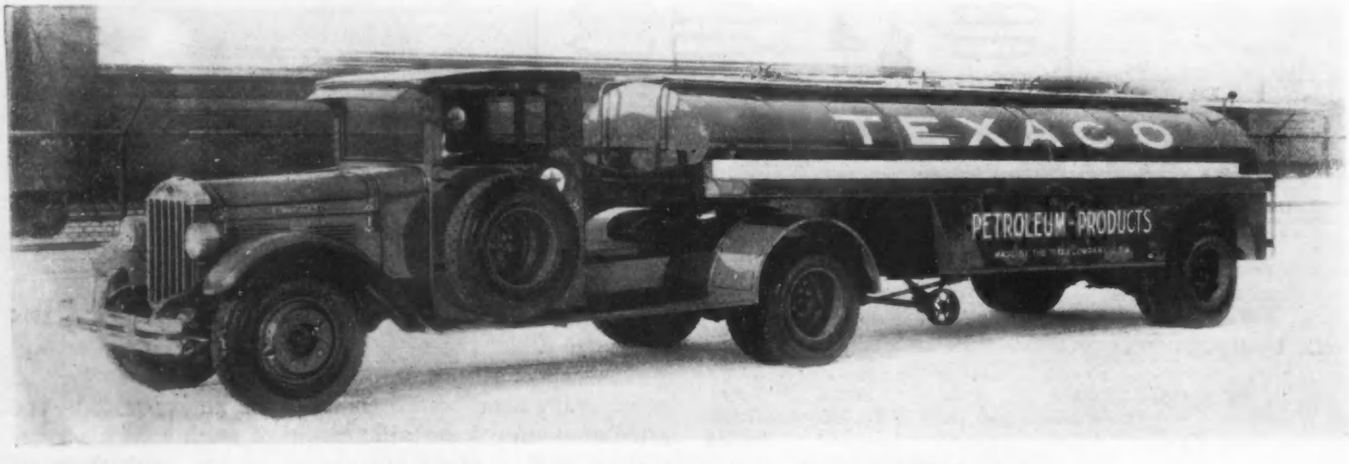

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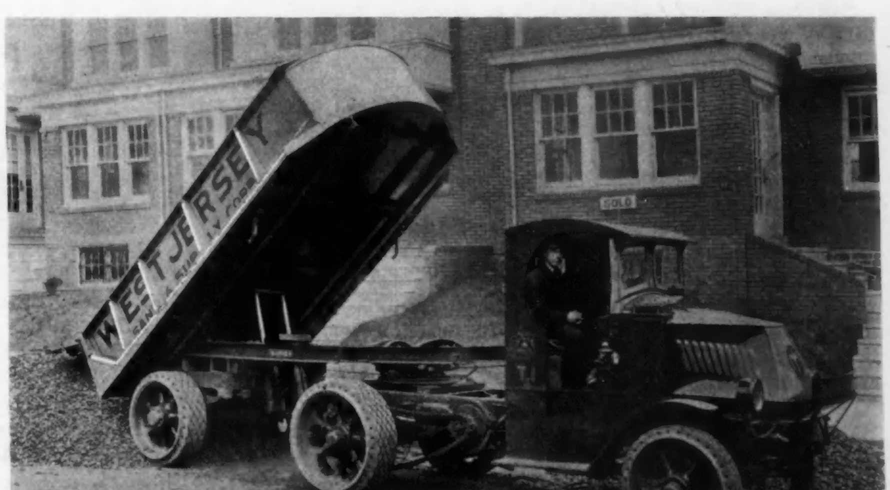

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SIX-WHEEL CROSSLEY CAR FOR KING GEORGE
Creeper Tracks Are Carried in the Rear Locker

Tires on Six-Wheel Vehicles

By G. M. Sprowls[1]

Transportation Meeting Paper — *Illustrated with* Charts and Photographs

Ten points on which the tire performance of four-wheel and six-wheel vehicles should be judged are listed by the author, who compares the two types of vehicle on these points and concludes that six-wheelers should give as good tire mileage as four-wheelers and that certain design changes can be made to improve the performance of tires on six-wheelers.

There is room, within the legal width-limit, for larger tires on a six-wheeler. Flat tires can be detected more easily with single than with dual tires, but dual tires reduce road delays resulting from punctures. Single right rear wheels of six-wheelers are subject to a large number of punctures.

Tires are a very important consideration in both motorcoach and truck operations. Operating costs may be considerably affected by the cost of tires per mile, and the difference between a satisfactory and an unsatisfactory operation may often depend upon the continuity of tire service. It is therefore fitting to point out the relative effect of six-wheel and four-wheel designs on tire equipment.

The facts herein presented are from observation of tire service in a great number of operations in the last 15 years, including most of the six-wheel installations in this Country. No attempt will be made to dwell on the characteristics or merits of the two types of vehicle in question except as they affect tire performance. Whether a six-wheel or an eight-wheel vehicle is superior to a four-wheel vehicle, as far as tires are concerned, depends on whether it shows superiority in the following respects: (*a*) average tire mileage, (*b*) cost per tire-mile, (*c*) number of tire changes, (*d*) ease of making tire changes, (*e*) riding-qualities, (*f*) safety from skidding, (*g*) traction, (*h*) relative capacity of vehicles on pnuematic tires, (*i*) effect of brake-drum heat, and (*j*) detection of flat tires.

Factors Affecting Tire Mileage

Many factors may affect tire mileage, but I will mention only those which may be varied according to whether the vehicle is a six-wheeler or a four-wheeler. The following are the principal factors of this character which I have observed in actual service:

(1) Load per tire
- (a) Normal Load
- (b) Abnormal Load
  - Car-track driving
  - Crown of road
  - Uneven inflation
  - One tire flat

(2) Braking
(3) Alignment
(4) Mechanical Conditions

With the same kind of service and road conditions, no other single factor has greater effect on tire wear than the load carried. Tire mileage drops off very rapidly as the load increases over the rated carrying capacity for tires of any given size. This effect is charted in Fig. 1, in which it is assumed that normal mileage will be secured with a load equal to the rated carrying capacity of the tire. The several curves for different sizes of tire show the percentage of variation from this normal mileage when the load is increased or decreased.

In the early days of the six-wheelers, their weight per pound of useful load was considerably less than that of a four-wheeler of approximately equal carrying capacity. Trucks used in impact tests by the United States Bureau of Public Roads in 1921 showed the following comparative weights of four and six-wheelers:

Type of Truck	Capacity, Lb.	Gross Load, Lb.	Weight of Truck, Empty, Lb.	Weight per Pound of Capacity Load, Lb.
Four-wheel	12,000	27,000	15,000	1.23
Six-wheel	17,500	28,700	11,200	0.64

With this large difference in weight per pound of capacity load, a considerably lower tire cost per pound of useful load was to be expected and was actually secured with the six-wheel vehicle.

Many changes have been made in both six and four-wheel chassis since the foregoing weights were taken. It is hard to get a true and direct comparison, because six-wheelers are usually built for larger capacities, but the following weights were furnished by a manufacturer making both four and six-wheel chassis and are given to show that the differential in weight between the two types has been somewhat reduced. The figures are based on bodies weighing 4500 lb. for the two lighter trucks and 5200 and 5500 lb. for the heaviest one.

Type of Truck	Capacity, Lb.	Gross Load, Lb.	Body Weight, Lb.	Weight of Truck Empty, Lb.	Weight per Pound of Capacity Load, Lb.
Four-wheel	9,500	22.000	4,500	12,500	1.32
Six-wheel	10,000	23,000	4,500	13,000	1.30
Six-wheel	14,300	30,000	5,200	15,700	1.10
Six-wheel	17,000	34,000	5,500	17,000	1.00

The weights of present motorcoaches of both four and six-wheel design vary greatly, as is evident from the following gross weights per seated passenger, including weight of passenger:

Six-Wheel Motorcoach				
Pounds per Passenger	418	498	585	703
Passenger Capacity	57	29	57	35

Four-Wheel Motorcoach				
Pounds per Passenger	510	582	625	687
Passenger Capacity	25	25	29	30

[1] M.S.A.E.—Manager, highway transportation department, Goodyear Tire & Rubber Co., Akron, Ohio.

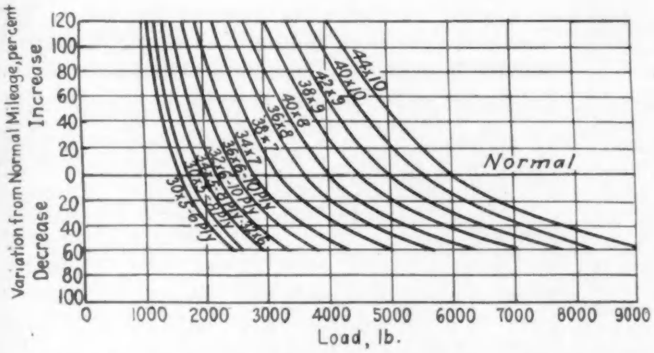

FIG. 1—VARIATION IN TIRE MILEAGE ACCORDING TO LOAD

The Mileage at Normal Load Is Indicated by the Horizontal Zero Line. The Curves Are Based on High-Pressure Motorcoach and Motor-Truck Tires of the Sizes Indicated

These weights are for chassis of different makes and bodies of different designs. The six-wheelers have both the lowest and highest weights per passenger. The fact that six-wheelers of one make are lighter than four-wheelers of another make, and vice versa, indicates that there is still a wide difference in weights. Any comparison of tire mileage between the two designs should be based, as nearly as possible, on similar construction details except for necessary differences. A design of one manufacturer who might tend toward heavy construction should not be compared with a design of another manufacturer who has reduced the weights of his vehicles to the minimum.

By abnormal loads, I mean those loads which burden the tires beyond their normal rating or those that are otherwise normal but which accompany unusually severe service or road conditions. A six-wheeler is much less likely than a four-wheeler to have any of its tires subjected to the unfavorable conditions of abnormal loading. This statement presumes that the former is equipped with single tandem tires and the four-wheeler with dual rear tires. Nothing prevents the use of tandem dual equipment on the six-wheel vehicle; in fact, as will be pointed out later, this is highly desirable under certain conditions.

In the case of car-track riding, one of the dual tires is often required to carry double its normal load, with lower mileage as a result. A flat tire on a dual wheel also throws a double burden on the other tire, but with somewhat less destructive effect because the load is not so much concentrated as on car tracks. Crowned roads and uneven inflation are other common causes of harmful overloading.

Six-wheel brakes which are not equalized will cause very rapid tread-wear. Any brake mechanism which is affected by spring deflection will tend to apply brakes more severely on one side than on the other, with resultant slippage and wear. The brakes of some of the early six-wheelers possessed this defect, which can be corrected by the use of power brakes.

A six-wheel vehicle should have some positive means of keeping the center and rear axles parallel to each other; otherwise, very fast tread-wear will result from a condition that is very similar to misalignment of front wheels. Fig. 2 portrays very plainly the result of conditions which should not exist. All of the tires were applied to a six-wheeler at the same time and were in service exactly the same length of time. Great difference in tread wear is evident. The center tires show the most wear, especially the left center. In comparing tires on two operations, one in which the equipment is such that the center and rear axles must be kept parallel and the other in which the axles may be out of parallel, the fact that the first operation does not show this excessive wear on the center tires leads me to conclude that alignment of the center and rear axles may have considerable to do with this wear. I do not believe grabbing brakes were responsible, although starting torque and braking doubtless accentuate this wear.

Manufacturers of six-wheel chassis do not agree as to the desirability of a third differential between the center and rear axles. I have not had the opportunity of observing tire conditions with a third differential, but I have observed no fast wear due to the use of two differentials, provided other conditions were right.

Number and Ease of Tire Changes

Six-wheel chassis in motorcoach service have shown up disadvantageously with respect to the number of tire changes on the right rear wheel. Fig. 3 gives the motorcoach miles per tire change under five different

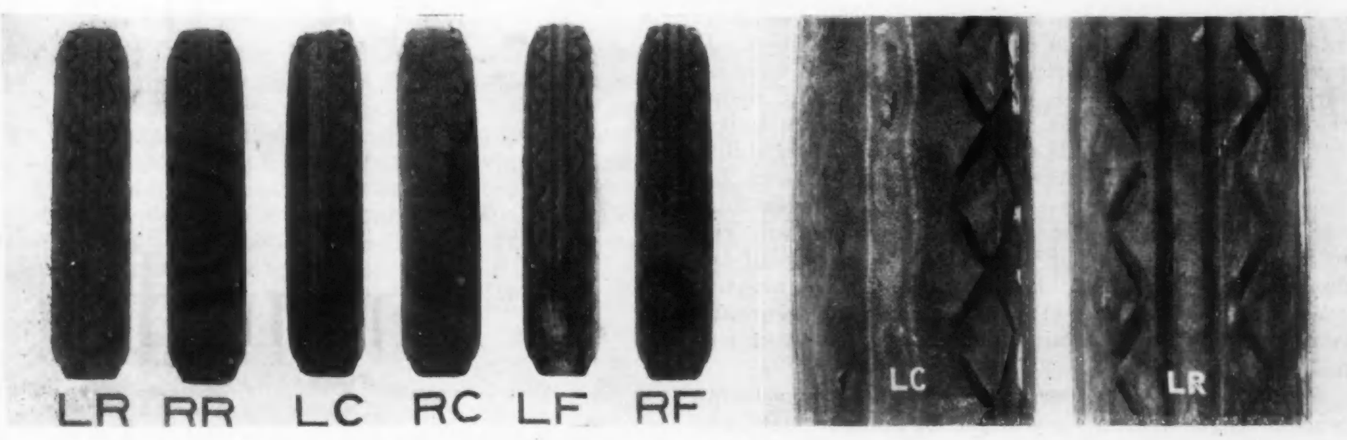

FIG. 2—ABNORMAL TIRE-WEAR

Six New Tires Were Applied to a Six-Wheel Vehicle at the Same Time, and All Six Were Removed When One Was Worn Down to the Breaker Strip. A Detail View of the Most-Worn Tire Is Shown at the Right, Together with the Tire That Was Subject to Apparently the Same Conditions

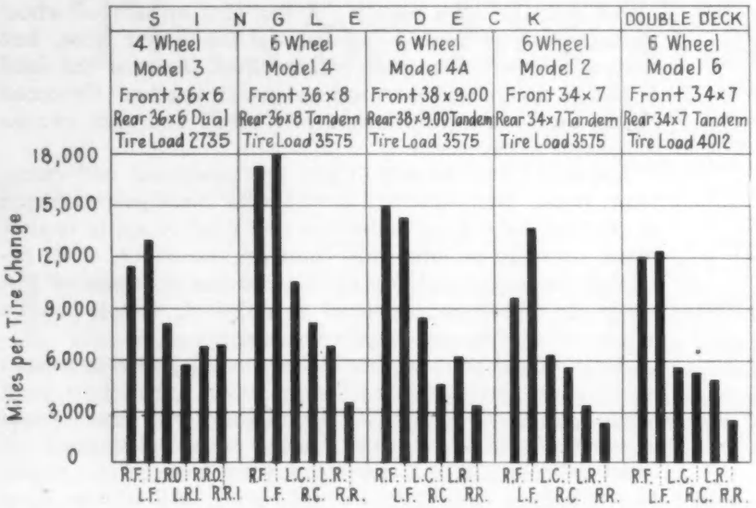

FIG. 3—MILEAGE PER CHANGE OF TIRES

The Places of the Tires on the Vehicle Are Indicated in This Figure as Follows: Right Front, RF; Left Front, LF; Left Rear Outside, LRO; Left Rear Inside, LRI; Right Rear Outside, RRO; Right Rear Inside, RRI; Right Center, RC; Left Center, LC; Right Rear, RR; Left Rear, LR

conditions. It should be noted that the six-wheel Model 4, with 36 x 8-in. tires, makes a very favorable showing against the four-wheel Model 3, with 36 x 6-in. tires, although the right rear wheel on the six-wheeler does require very frequent changes. The reason I make this particular comparison is that undersized tires are often used and the results are quoted without making due allowance for the overload factor. For example, the Model 6 double-deck motorcoach, with a considerably higher tire-load than Model 4, is equipped with 34 x 7-in. tires because of viaduct conditions which will not permit the use of a larger tire size. It was to be expected that failures would result more frequently under such conditions.

Considerable talk has been heard to the effect that the right center tire of a six-wheeler sets up nails and tacks so that the right rear tire picks them up. I have had a slow-motion picture taken of a six-wheel truck going over a number of nails of different sizes at about 30 m.p.h. The nails were counted before and after the truck went over them, and none were picked up by the tires.

Several reasons why a single tire should give higher mileage than duals have already been mentioned. If road delays on single tires are so frequent as to cause serious concern, the use of dual tires should reduce their number. This does not mean that the dual tires would pick up fewer nails and screws; in all probability they would have a greater number of punctures, because the tires would be smaller and the threads thinner. However, many motorcoach operators will run to the end of the line or to the garage on one of the dual tires if the other is punctured. This practice does reduce road delays; but it cannot be generally recommended, as it certainly increases the cost of tire mileage.

Fig. 4 compares the performance of a six-wheeler on tandem single tires, a six-wheeler on tandem duals, and a four-wheeler on duals.

Evidently it is easier, quicker and less costly to remove a single tire than to remove one in a dual combination.

A very marked trend toward the use of balloon tires for both motorcoach and motor-truck service is evident. This is due quite as much to generally satisfactory results as to the improved riding-qualities of the balloon tire. Balloon tires show to special advantage on long, hot runs and over rough roads.

Very few dual-wheel chassis on the market can use balloon tires larger than 9.75-in. size without exceeding an over-all width of 96 in., which is now the legal limit in most States. I have been told that further reduction of the frame width would seriously reduce the stability. A six-wheeler or other single-tire chassis has the advantage in this respect, because of the greater space available for large tires.

Skidding and Traction

The six-wheel design, having four wheels rather than two in the rear, should and does reduce the liability to side skidding. It permits the non-skid portion of each of the four tires to function, whereas only two of the four rear-wheel tires of a four-wheel vehicle are effectively applied in preventing side motion after a skid has started, because the other two tires must move over a surface wiped clean by their mates.

The six-wheel vehicle with four driving wheels shows an advantage on rough roads, because of the improbability that more than one wheel at a time will be off the ground and spinning. A four-wheeler has this slippage on both of the tires on one rear wheel when that

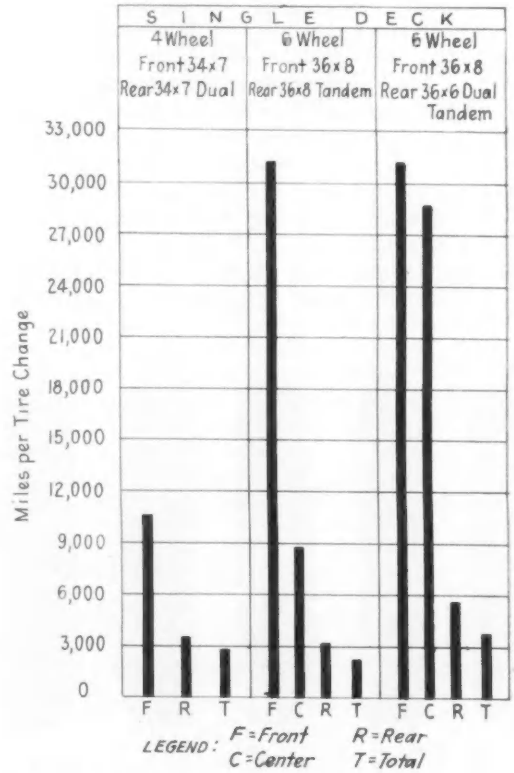

FIG. 4—MOTORCOACH TIRE CHANGES WITH SINGLE AND DUAL TIRES

The Tires Are Indicated in This Figure as Follows: Front, F; Center, C; Rear, R; Total, T

wheel returns to the ground after a bounce. Increased slippage of course means more tire wear.

Relative Capacity on Pneumatic Tires

Disregarding State legislation that permits greater loads on six-wheel vehicles than on four-wheel vehicles, the restriction of width to 96 in. in most States really limits the maximum carrying capacity, because of the space required for tires outside of the frame and within the legal width. As far as this limitation is concerned, just twice as much load can be carried on the pneumatic tires of a six-wheel vehicle as of a four-wheel vehicle. This is an important point, especially in motor-trucks of the larger carrying capacities, on which the six-wheel design now seems to be making the greatest progress.

Effect of Brake-Drum Heat

Much of the heat from the rear-wheel brake-drum reaches the rim and tire bead, with dual tires, where there is small clearance between the brake-drum and the rim of the tire. Tire-bead failures from this source were quite numerous a few years ago. Tire manufacturers have greatly increased the ability of their beads to resist this destructive heat, and many motorcoach and truck manufacturers have increased the clearance between the drum and the rim to give increased ventilation. Still, tire mileage is lost and the life of the tube is greatly decreased when frequent braking is required, even though the heat does not result in an actual bead blow-out. Thinning out of tubes may be caused, with resulting leaks and road delays.

A six-wheeler having single tires in tandem could be designed with reversed wheels. This would avoid the difficulty presented by the present design, in which the rim and tire surround the brake-drum. Separation of rim and brake-drum is highly desirable. Reversal of the wheel would vastly improve the ventilation and greatly reduce the temperature of the tire and tube. Fig. 5 shows the results of thermocouple tests of wheels offset from the brake-drum.

Detection of Flat Tires

Considerable loss has resulted from running tires flat. The cords of the inner plies of fabric are literally chewed to pieces by such abuse, requiring the tire to be prematurely withdrawn from service. The fact has been definitely proved that a driver can detect a slow

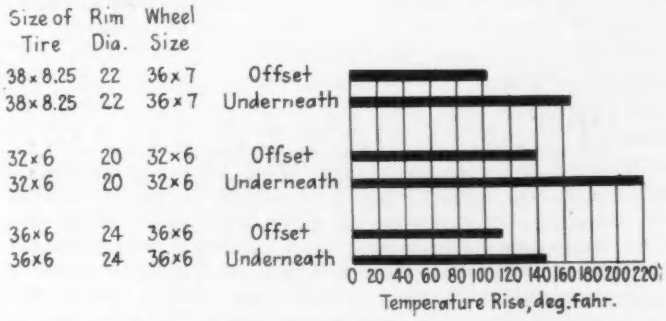

FIG. 5—TEMPERATURE EFFECT OF OFFSETTING BRAKE-DRUMS

Temperature Rises at the Bead of Motorcoach Tires, Based on a Constant Brake-Drum Temperature 475 Deg. Fahr. Higher than Atmospheric. Budd Disc Wheels Were Used, Located at the Rear, Inside

leak on a front wheel before the tire is damaged; and, in case of a cut causing the tire to go entirely flat, he can stop in time to avoid injury to the casing. Many drivers have told me that they are able to detect a flat tire on a rear dual wheel. I myself have observed a driver making a special stop because he had sensed that one of his right rear tires was flat. Nevertheless, it is evident that to detect flat tires is easier on a single mounting than on a dual mounting.

In conclusion, I would state that a six-wheel truck or motorcoach should show as high tire mileage as a four-wheeler, and that the tire performance of a six-wheeler can be greatly improved by changing the design in such a way as to eliminate the avoidable abuses mentioned in this paper.

Four-Wheel Drives for Six-Wheel Chassis

(*Concluded from p.* 588)

greatly complicates the design. A way of introducing such a differential is shown in Fig. 12. This design is as yet purely experimental. Power from the engine goes through a distributing differential mounted as an integral part of the forward driving-unit and is distributed between the forward axle and a gear train that connects with the rear driving-unit. This construction gives complete equalization of the power among all four rear wheels.

Fig. 13 illustrates another differential arrangement in which the second propeller-shaft passes through a hollow worm in the forward driving-unit to the second unit. This design involves production and design problems that have not as yet been mastered. Experience alone will prove whether such a differential is necessary. Tire mileages on six-wheelers having no third differential have been very high, and doubt exists as to whether a third differential is essential.

The Employment of Less Volatile Fuels for Motorcoach Engines[1]

By GEORGE A. GREEN[2]

THE AMERICAN public demands that, in safety, comfort, appearance, speed, acceleration and deceleration, motorcoaches shall compare favorably with the present-day automobile, according to the author. These demands have resulted in a substantial increase in weight that has required the use of much larger engines, and this has brought about a tremendous increase in fuel consumption. Since fuel costs represent a large percentage of the total cost of operation, the possibility of decreasing these expenditures is receiving considerable attention. In addition, and apart from the increase in fuel usage resulting, taxation is causing grave concern.

The author describes the fuel issue as it now exists in the United States. Data are submitted showing the tax situation, costs and refining operations, the potential saving assuming the employment of the less volatile fuels, their possible method of employment, advantages, disadvantages and the like. The data concerning prices of crudes and their derivatives were obtained from accredited sources.[3]

After outlining the commercial situation, the author analyzes the uses of the crudes and discusses their derivatives. The cracking process is described and the determination of costs and of losses is commented upon, together with costs at the sources. The Diesel system, hot carburetion and cold carburetion, as means of employing the less volatile fuels in internal-combustion engines, are analyzed separately and compared. Statements are made concerning the use of kerosene as a fuel and the criticism is made by the author that the term kerosene does not designate a definite product and that the specifications are of too wide a range to permit determination of the suitability of any such fuels when used in connection with present-day heavy-duty motorcoach engines. After summarizing the paper, the author concludes that the available evidence concerning the crudes and their derivatives points to the fact that we have no alternative other than to continue the use of our present fuel standard, namely, gasoline, in spite of hopes to the contrary.

COMPLETE lack of standardization exists at present in the various States as regards both the amount of tax on motor fuel and the classes of fuel on which the tax is applied. The tax varies from 1 to 5 cents per gal., the average tax being 2.8 cents per gal. In some cases the law specifically states that the taxes apply only to gasoline; in other cases the kerosenes, gas-oil and fuel oils are included. In general, the revenue derived from these taxes is applied in connection with road-building programs. Much misunderstanding of this subject is prevalent as a result of the involved conditions existing with respect to fuel taxation, and in some instances operators feel that the employment of fuel other than gasoline will render them immune from taxation. While at present this is true in a limited number of cases, it seems reasonable to suppose that any general use of such fuels will result immediately in modifications of the laws, because the bills obviously have been written with the object of taxing all vehicles that operate on the highways.

Taxation and Legislation

When considering the tax issue, it must be remembered that gasoline-tax bills may be amended at any legislative session. It also should be noted that the constitutions of the various States determine the frequency with which the regular sessions are held. In some States regular sessions are held annually; in others every two years; and in a few every four years; but the Governor of any State may, at his discretion, call a special session at any time. The present gasoline taxes inflict a very real hardship on operators in a number of instances and, unfortunately, considerable likelihood exists of further taxation of a similar nature.

The Commercial Situation

To understand the commercial situation with regard to gasoline, fuel oil, crude oil and the like, it is necessary to study the costs and the different refining operations by means of which the crudes are converted into the various refined products. As a basis for this discussion, prices[4] of various products are given in Table 1. The figures merely represent a few typical instances of the different costs of the products. A similar list of prices appears in each week's issue of the *Oil and Gas Journal,* and the specific price of any petroleum product at any time can be determined therein. It should be noted that barrel capacities are figured at 42 gal. and that the prices per gallon were obtained on this basis.

The possibility of profit insofar as it concerns the merchandising of the crudes and their derivatives is largely dependent upon the demand for gasoline. The percentage of lubricating oil per unit of crude is small, as is also the selling price of this substance at its source, and the cost of handling is high; further, there is a limit to its possible sale. Actually, over the last several years, the proportion of lubricating oil per unit of crude has been deliberately curtailed. This is ap-

[1] Prepared for presentation at the World Engineering Congress, Tokio, Japan, Oct. 29 to Nov. 7, 1929.

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[3] The sources of the data are the United States Bureau of Mines, the American Society for Testing Materials, reports of the National Automobile Chamber of Commerce, *National Petroleum News, Oil and Gas Journal,* and Petroleum and Its Products, by William A. Gruse.

[4] See *Oil and Gas Journal,* March 14, 1929, pp. 140 and 141.

TABLE 1—TYPICAL INSTANCES OF THE DIFFERENT COSTS OF THE VARIOUS REFINED PETROLEUM PRODUCTS

Description	Cost per Gallon at Source, Cents
U. S. Motor Gasoline, of 437-deg. fahr. end-point	6.75
Kerosene	6.25
Crude Oil at from 60 cents per bbl. (1.4 cents per gal.) to $1.44 per bbl. (3.3 cents per gal.) depending on the particular crude and specific gravity; for discussion, Oklahoma Crude of 35 deg. Baumé at $1.17 per bbl. is taken	2.80
22-26 Fuel Oil at 65 cents per bbl.	1.50
32-36 Gas-Oil, straw-color	3.25
124-126 White Crude Scale Wax at 4 cents per lb.	30.00
280 Viscosity, 5-Color, 25-30 Cold-Test Lubricating Oil	12.00
Oklahoma 600 Steam-Refined Light-Green Cylinder-Stock Lubricating Oil	9.50
Oklahoma 150-160 Viscosity, E-Color Bright-Stock Lubricating Oil	29.00
Gulf Coast, 2½-Color 500-Viscosity Pale Filtered Lubricating Oil	15.75

parent from the Bureau of Mines figures in Table 2, which are based upon the volume of crude oil run to refineries.

In connection with this issue, Table 3 shows the quantities of lubricating oil used by motor-vehicles and by the industry in general from 1918 to 1928, as obtained from Bureau of Mines statistics. The motor-vehicle registration statistics were obtained from National Automobile Chamber of Commerce reports, as were those for the average motor-vehicle consumption, assumed at 15 gal. per year per vehicle. The column headed "Remainder" represents the calculated number of gallons left over for general industrial use after having deducted the estimated automotive consumption. The column headed "Approximate Production per Vehicle" includes all the lubricating oil, whether used by industry in general or by the automotive industry.

It is clear from Table 3 that roughly twice as much lubricant was consumed in the United States in 1928 as in 1918, although its percentage per unit of crude was reduced by about one-half. In round figures, comparing 1928 and 1918, the motor-vehicle registration was quadrupled and it can be assumed that the automotive oil-consumption increased in like proportion, but the balance of lubricant left over remained substantially the same through recent years. The assumption is that the quantity was sufficient to meet the demand.

TABLE 2—PROPORTION OF LUBRICATING OIL PER UNIT OF CRUDE

Product	1918	1928
Lubricating Oil Produced, bbl.	20,035,000	34,659,000
Crude Oil Run to Refineries, bbl.	326,000,000	912,000,000
Percentage of Lubricating Oil Produced	6.1	3.8

TABLE 3—QUANTITIES OF LUBRICATING OIL USED BY MOTOR-VEHICLES AND BY THE INDUSTRY IN GENERAL

Year	Motor-Vehicles Registered	Domestic Consumption, Gal.	Motor-Vehicle Consumption, 15 Gal. per Vehicle	Remainder, Gal.	Approximate Production of Lubricating Oil per Vehicle Registered, Gal.
1918	6,146,617	580,552,186	90,000,000	490,000,000	94
1919	7,565,446	568,382,979	115,000,000	455,000,000	75
1920	9,231,941	609,750,289	140,000,000	470,000,000	66
1921	10,464,715	530,273,196	155,000,000	375,000,000	50
1922	12,239,853	626,299,377	185,000,000	445,000,000	51
1923	15,092,197	739,938,025	225,000,000	515,000,000	49
1924	17,595,373	761,208,000	265,000,000	495,000,000	43
1925	19,954,347	864,402,000	300,000,000	565,000,000	43
1926	22,001,393	947,730,000	330,000,000	620,000,000	43
1927	23,224,144	908,628,000	350,000,000	560,000,000	39
1928	24,750,000	971,754,000	380,250,000	591,504,000	39

Use of the Crudes

The 1.4-cent per gal. grade of crude is a thick product, at least as viscous as heavy engine-oil, containing little if any gasoline and kerosene but with varying amounts of water, salt, sand, clay, sulphur, wax, tar and asphalt. The 3.4-cents per gal. grade is similar to the 1.4-cent grade except that it is more fluid and contains larger amounts of gasoline and kerosene.

Crudes can be used in (*a*) open-hearth furnaces, steam-boiler installations and the like where the burners do not have small passages; (*b*) heavy slow-speed Diesel-engines which do not have very small-bore nozzles since, generally speaking, no preliminary treatment is necessary except straining and possibly heating to provide the necessary fluidity to permit the fuel-pump to operate properly; and (*c*) small Diesel-engines, assuming the elimination of water, sand and other sediment, and that the oils are heated so as to provide the required fluidity. Provision also would be necessary to keep the nozzles clean because they are likely to become plugged with asphalt and dirt. These fuels cannot be used in an automobile engine operating on the Otto cycle because (*a*) proper distribution and vaporization are impossible; (*b*) with ordinary compression-ratios there would be excessive knocking; and (*c*), in general, the odors would be sufficiently bad to render their use impracticable. It also should be noted that this condition would obtain regardless of the type of engine.

To overcome these defects, the crudes must be refined, a process which includes (*a*) separation of the crude oil into various cuts based on boiling-point, such as gasoline, kerosene, gas-oil and the like, which is effected by distillation and fractionation; (*b*) removal of objectionable impurities such as sulphur by suitable chemical treatment; and (*c*) cracking, that is, converting oils from a high to a relatively low boiling-point by means of heat.

The Crudes and Their Derivatives

The more expensive crudes contain a larger amount of gasoline and other light fractions present initially as such. Table 4 gives the yield from the average Mid-Continent crude[5].

The gasoline obtained directly by distillation from the crudes without appreciable cracking can be used in ordinary automobile engines, and very little if any further refining is required for gasolines so produced; but, although the original crude oil might have the com-

[5] See Petroleum and Its Products, by William A. Gruse, p. 118, McGraw-Hill Book Co., Inc., 1928, New York City.

TABLE 4—YIELD FROM THE AVERAGE MID-CONTINENT CRUDE

Product	Per Cent
Gasoline and Naphtha	21.34
Kerosene	9.77
Gas-Oil	34.13
Neutral Lubricating Oils	5.88
Wax	1.88
Cylinder Stock	23.50

TABLE 5—HOW THE CRUDE OIL IN THE UNITED STATES FOR 1928 WAS REFINED

Product	Per Cent
Gasoline and Naphtha	41.3
Kerosene	6.6
Gas-Oil and Fuel Oil	46.7
Lubricants	3.8
Wax	0.2
Miscellaneous and Loss	1.4

TABLE 6—PERCENTAGES OF PETROLEUM PRODUCTS PRODUCED FROM CRUDE OIL RUN TO REFINERIES

Product	Per Cent 1916	Per Cent 1928
Gasoline	19.8	41.3
Kerosene	14.0	6.6
Gas-Oil and Fuel Oil	45.0	46.6
Lubricants	6.0	3.8

position shown in Table 4, the division of the product as outlined is impractical because of market conditions. Obviously, the refiner must convert the crude oil into products which can be sold and, according to preliminary data from the Bureau of Mines, the crude oil in the United States for the year 1928 was refined as shown in Table 5.

The Cracking Process

Cracking may be described as the process of changing the chemical composition of a non-volatile viscous fluid to a more volatile and more fluid substance by the use of heat, either with or without pressure. Substantial improvements have been effected with respect to the cracking process, and it is now possible to obtain a considerably higher percentage of gasoline. For example, the yield of gasoline and naphtha for the average Mid-Continent crude, as given by Gruse, is 21.34 per cent; but the gasoline and naphtha actually produced in 1928 averaged 41.3 per cent. The figures in Table 6, based upon the volume of crude oil run to refineries, illustrate this point and show the percentages of gasoline, kerosene, gas-oil, fuel oil, and lubricants, for 1916 and 1928. At present, from every gallon of crude oil we are obtaining about 45 per cent of gasoline, and this is more than sufficient to meet demands. The gasoline percentage could be increased to be between 65 and 85 per cent if the demand develops.

A large part of the lubricating oils, part of the gas-oil and fuel oil, and a portion of the kerosenes must be converted into gasoline by the cracking process. Assuming the cost of crude oil at 2.8 cents per gal., or $2.80 per 100 gal., the cost and accounting on the basis of the quantities produced in the United States per 100 gal. of crude are shown in Table 7.

The Determination of Costs

The cost of the crude oil, that of 35-deg. Baumé Oklahoma crude, has been assumed at $2.80 per 100 gal. and the value of all the refined products except gasoline at $2.13, which is 67 cents less than the cost of the crude. If the gasoline is sold at 6.75 cents per gal. there remains a margin for profit, labor, refinery costs of all kinds, sales costs and the like, of **$4.92 — $2.80 = $2.12 per 100 gal. or 2.12 cents per gal.**; and, if this amount is uniformly distributed, each gallon of the refined product would cost 2.80 cents for the crude oil and 2.12 cents for refining, or a total of 4.92 cents according to the assumptions I have made.

TABLE 7—COST AND ACCOUNTING OF CONVERTING PRODUCTS INTO GASOLINE ON THE BASIS OF QUANTITIES PRODUCED IN THE UNITED STATES PER 100 GAL. OF CRUDE

Product	Per Cent	Approximate Value per Gallon, Cents	Value from 100 Gal. of Crude
Gasoline and Naphtha	41.3	6.75	$2.79
Kerosene	6.6	6.25	0.41
Gas-Oil and Fuel Oil Combined	46.7	2.50	1.17
Lubricants	3.8	13.00	0.49
Miscellaneous and Loss	1.4	...	...
Wax	0.2	30.00	0.06
Value of All Products, Including Gasoline			$4.92
Value, Exclusive of Gasoline			$2.13

Because the supply exceeds the demand, the refiner cannot get 4.92 cents per gal. for a large part of his product, such as the gas-oil and fuel oil; consequently, he must sell the remainder at a price high enough to absorb this loss. In other words, refinery costs are not calculated on the expenditures incurred in connection with the production of a specific refined product. The refiner simply tries to get enough for each refined product so that his total receipts will not be less than his costs. If the engine of whatever type chosen can operate on the gas-oil that is left after the other products have been removed, the basic price of this fuel is 3.25 cents per gal.; but, if engines should be designed to use large quantities of it, the refinery costs would then be spread out so as to distribute them over the gas-oil also, thereby causing it to approach very closely to gasoline in price. With gas-oil at 3.25 cents per gal. and gasoline at 6.75 cents per gal., there is only a 3.5-cent differential, and if the difficulties due to odor, sulphur, gums, tars, lack of volatility and absence of uniformity were considered of less importance than 3.5 cents per gal., then, under present conditions, gas-oil could be used if we had an engine that would burn it. If gas-oil cannot be used, then kerosene at 6.25 cents per gal. or gasoline at 6.75 cents per gal. must be employed.

The Determination of Losses

The oil companies naturally are reluctant to disclose their cost figures, but the statement has been made that the cost of converting gas-oil into gasoline, that is, by cracking it, is 1.5 cents per gal. In general, about 70 gal. of gasoline per 100 gal. of gas-oil can be obtained by this method, but the total cost must include not only the cracking charge but also the loss due to the lower price at which the remaining coke and tarry product can be sold. In short, the remaining 30 gal. will represent a value of about 1 cent per gal. It should be mentioned that this material has very little commercial use and is not even suitable for employment as heavy-duty slow-speed Diesel-engine fuel. Figuring the 32-36 straw-color gas-oil[6] at 3.25 cents per gal., the loss will be $1.05 for cracking 70 gal. at 1.5 cents per gal. and 67.5 cents for the loss on 30 gal. at approximately 2.5 cents per gal. or a total loss, based on 70 gal., of $1.725; that is, about 2.5 cents per gal. These figures show that the basic cost of the gasoline will be about 2.5 cents per gal. higher than that of the gas-oil.

[6] See *Oil and Gas Journal*, March 14, 1929, p. 140.

With some of the newer cracking processes, it is claimed that a considerably higher percentage of gasoline can be obtained from the gas-oil. Under such conditions less coke and tarry matter would be left over which must be disposed of as fuel oil. Assuming this to be true and that the processes become generally used, the 2.5-cent basic-cost differential between gas-oil and gasoline should decrease proportionately.

The Costs at the Sources

In studying the fuel question from the viewpoint of price, consideration has been given only to costs at the source because all other charges such as for freight, handling, profit and the like must, in the last analysis, be similar, regardless of the character of the fuel. It is believed also that, in the end, any form of fuel tax applying to road vehicles will be made to apply to all fuels. A summary of the approximate basic costs of the different fuels, at the source, is shown in Table 8.

As to the nature of the problem, it is clear that the differential in the basic costs of the different products is very small and that the cost of converting these products to gasoline is low. Since it is possible to refine crude oil to obtain varying percentages of the final products, depending upon the demand, the problem is not, How can non-volatile oils be burned? but, How can we secure the maximum amount of energy from a given unit of fuel and still keep before us commercial requirements? This means freedom from odor, detonation, gumming and corrosion; and also is influenced by engine size, weight, cost, durability, dependability, flexibility, ease of operating, servicing and the like.

The particular kind of engine which will give the best results, taking into account such factors as the foregoing, should then be determined. If it is found that such an engine requires a more expensive fuel than some other engine, the two engines must then be compared to see whether the saving in the basic fuel-cost is sufficient to offset its disadvantages, which may be heavy weight, high cost, or the like. For certain types of service, such as for engines on large ocean-vessels, this analysis may show that the Diesel engine operating on gas, crude or fuel oil may be the best. In this case the total weight of the engine and fuel for a long trip, high fuel-efficiency and the decreased fire hazard with a fuel that is not very volatile, are in favor of the Diesel. For other installations such as on passenger automobiles, the engine operated on gasoline may be the best. In this case the lower weight and first cost of the gasoline engine, together with such advantages as flexibility, may outweigh such disadvantages as higher fuel-consumption. For other purposes, such as for motor-trucks and motorcoaches, the decision must be made upon the factors involved in the particular case under consideration.

Considerations Involved in Fuel Usage

Having briefly discussed the tax situation, costs and refining operations, the potential saving assuming the use of the less volatile fuels, and other subjects, we will now consider the several possibilities concerning the employment of these fuels for internal-combustion engines; namely, the Diesel system, hot carburetion, and cold carburetion.

When considering the use of fuel other than gasoline, we are faced with the employment of the non-volatile elements; namely, the crudes and gas-oils, the latter being more fluid and more volatile than the crudes since they already have been partly cracked. But in the light of present knowledge the only known practical method of employing them is by means of the Diesel system. Under this heading are included all engines in which fuel injection is employed, regardless of whether ignition is by means of compression, pre-heating or the conventional electrical method.

In America, not much is known to date regarding the practicability of using Diesel engines satisfactorily in motorcoach service, but it is reported that progress has been made abroad, particularly in Germany. However, the possibility of employing the lower-priced fuels, at the same time obtaining reduced fuel consumption for a given power output, is decidedly interesting. Further, the lessened fire risk is attractive.

Experience with Diesel engines indicates that in their present state they are expensive, heavy, rough and not responsive over a wide speed-range. Further, many troubles are to be expected with the fuel-injection system, particularly on account of clogging. A point to be remembered is that the fuel must be free from any foreign matter which might interfere with distribution, because the jets or orifices through which the fuel must pass are exceedingly small in some instances. It seems reasonable to suppose that a very considerable amount of development work yet remains to be done before these conditions can be remedied; but other systems exist which may permit the employment of the less volatile fuels, although the Diesel engine appears to have the most practical possibilities.

TABLE 8—APPROXIMATE BASIC COSTS AT THE SOURCE SUMMARIZED

Product	Cents per Gallon
Fuel Oil, as a residue after the removal of all valuable products including gas-oil	1.50
Crude Oil, average, direct from wells	2.80
Gas-Oil, average, an unrefined distilled product less volatile than kerosene	3.25
Kerosene	6.25
U. S. Motor Gasoline	6.75

Hot Carburetion

Any more or less standard type of carburetion system having, in addition, a considerable amount of hot-spotting which is necessary to assist in the process of vaporization, is termed hot carburetion; it will, after a fashion, permit the burning of certain of the less volatile fuels, but numerous difficulties must be overcome such as those due to decrease in volumetric efficiency, crankcase-oil dilution, detonation, hard starting, gumming, carbon formation, and high sulphur-content.

Hot carburetion represents the simplest possible method of employing the less volatile fuels; consequently, attempts are being made to utilize this system and a limited number of vehicles are in operation at present the engines of which burn, more or less satisfactorily, a naphtha having a volatility between those of gasoline and kerosene. This fuel is much superior to kerosene in volatility and is made by mixing gasoline with a light furnace-oil, which latter is a distillate unsuitable for use as kerosene and having a boiling-point too high for its inclusion with gasoline. This fuel cannot correctly be described as a gas-oil.

Some furnace oil is merely kerosene that cannot be

sold as such for lack of a market. In general, it is a by-product of the cracking of gas-oil to make gasoline. It is a fraction having a volatility between those of gasoline and kerosene and is so near to being gasoline that any attempt to crack it further to gasoline would cause such a large amount of the product to be broken up to a non-condensable gas that the process cannot be regarded as economical while the product can be sold without further cracking.

The vehicles burning naphtha, to which reference has been made, are equipped for gasoline-electric propulsion, a type of equipment which is more adaptable to the use of the less volatile fuels than are the conventional gear-driven designs, because the engines operate more nearly on a constant-speed basis.

When considering the possible use of the less volatile fuels it must be appreciated that, at present, the refineries are able to produce more gasoline than they can dispose of readily. This results in a considerable price fluctuation but distributors are, in general, unwilling to lower their prices except by general agreement because any other plan results in a price war. Actually, a possibility exists at present of obtaining a fuel closely resembling gasoline but sold under some other name at a figure substantially less than current market-rates. It consequently is conceivable that in certain instances operators might think they are burning fuel oils successfully when, actually, this is not true.

It should be mentioned that a further general lowering of prices in the petroleum industry seems unlikely. A large number of refineries were operated at a loss in 1927, and 1928 was not an outstandingly prosperous year. But monumental efforts are now being made to curtail crude production and thus stabilize the economics of the oil industry so that operating profits will be less insecure.

Disadvantages of Hot Carburetion

Decrease in Volumetric Efficiency.—With conventionally designed engines in which attempts are made to employ fuels having an end-point beyond that of the Federal or Navy specifications, namely, 437 deg. fahr., it is necessary to apply a very considerable amount of heat and a decrease in volumetric efficiency results. From 10 to 20 per cent of the total power-output may thus be lost and, since virtually all motorcoaches are today under-engined, this is a matter of very great importance.

Crankcase-Oil Dilution.—This is one of the controlling factors which determine the character of the fuel to be used and, if the end-point exceeds 437 deg. fahr. by any considerable amount, crankcase-oil dilution occurs; that is, an appreciable quantity of fuel passes the pistons and rings and enters the crankcase. One method of avoiding this is to materially increase the engine operating temperature, the Diesel being an extreme example.

Detonation.—A factor that precludes the use of fuels having a high end-point is detonation, or knocking. The chemical composition of the less volatile fuels in general predisposes them to this condition, and the higher temperature which is necessary properly to vaporize such fuels prior to distribution makes this situation markedly worse; but this condition can be substantially improved if an antiknock agent such as ethyl fluid is used.

Hard Starting.—Obviously, cold starting with such a fuel is impossible and it therefore is necessary to employ an auxiliary fuel-system using gasoline. Such a scheme seems practicable but introduces a number of complications, particularly where large operations are concerned. Two fuel-systems with all their connections and piping are needed and, since it is reasonable to suppose that only a relatively small quantity of gasoline will be carried, a possibility always exists that the gasoline will be exhausted at the critical moment. As an alternative, some kind of preheating device can be installed immediately above the venturi throat and possibly can be operated electrically, but a considerable amount of electrical energy is required and no entirely satisfactory system has as yet been developed.

Gumming.—Unless the gas-oils are subjected to a refining process, the presence of gums renders possible the sticking of the valves, carbureter parts and piston-rings, and all gas-oils contain unstable elements of which a part ultimately may be deposited in the form of gum.

Carbon Formation.—Because of lack of refinement and difficulties in effecting proper combustion, a considerable amount of carbon may be deposited, particularly on the piston-heads and around the valves and valve-stems. Excessive deposits will affect the operation of the engine; for example, preignition may occur. Also, the deposits may be sufficiently thick to affect the compression space and, since this condition varies for the different cylinders, the performance of the engine ultimately will suffer, particularly with regard to smoothness.

High Sulphur-Content.—On account of lack of refinement of the fuel, the presence of sulphur is likely and this renders corrosion possible under conditions in which water can collect in the crankcase; specifically, if engines are operating under light duty and do not reach a high temperature. In addition, sulphurs of the corrosive type will bring about the disintegration of the fuel strainers and lighter metal carbureter parts.

To summarize, while hot carburetion may permit the operation of motorcoach engines using certain of the less volatile fuels, assuming sufficient heat is available for proper vaporization, the disadvantages are of such a serious nature that it is extremely doubtful whether the proposal has any real merit.

Cold Carburetion

Any system of carburetion wherein the fuel-air mixture has no heat purposely added prior to its entry into the combustion-chamber may be termed cold carburetion. The manifolds with which engines were equipped in the earlier days of the industry, without provision for either hot air or hot-spotting, fall within this very general classification, but, while this arrangement proved satisfactory with the then highly volatile fuels, on account of the less volatile fuels which are now used the old type of manifolding cannot be employed because:

(1) With the more volatile fuels, distribution of the mixture in equal quantities presented no particular difficulties because it was largely in the gaseous state; but, with the less volatile fuels, the mixture, after leaving the carbureter, still contains quantities of liquid which collects on the walls of the manifold and makes uniform distribution impossible.

(2) The low intake-velocities incident to large-section manifolds result in poor atomization, and hard starting is a direct consequence of failure to lift the fuel into the combustion-chamber.

In an attempt to overcome cold-carburetion problems, the Delco Products Corp., a division of the General Motors Corp., has for some years been actively engaged upon the development of a system of manifolding and carburetion known as Gemcold, and when discussing cold carburetion in its application to the less volatile fuels, it should be understood that the arguments advanced here in its favor refer to this particular system. It is a system having a carbureter assembly and a primary and a secondary manifold. The primary manifold consists of tubes of small diameter connecting an individual carbureter-jet with each cylinder or pair of cylinders; the secondary manifold surrounds the primary one and resembles a simple conventional manifold. The function of the primary manifold is to supply all fuel to the engine and, in addition, the complete fuel-air mixture for starting and part-throttle operation. The secondary manifold is inoperative at low throttle-openings, but supplies the additional air required throughout the wider-throttle and speed ranges.

Advantages of Cold Carburetion

The important advantages of cold carburetion seem to be its volumetric efficiency, easy-starting ability and ease of adaptation. Regarding its volumetric efficiency, the temperature of the air is relatively low and, because of its introduction into each cylinder in this state, higher volumetric efficiency is to be expected. For the same reasons it also should be possible to increase the compression ratio slightly without increasing knocking or detonation. This condition certainly would obtain with gasoline, but when the less volatile fuels are used it may be offset by their greater detonating tendency.

Easier starting is to be expected if we assume good mechanical condition and correct engine design, because excellent atomization is possible on account of the high velocity in the primary manifold and past the jets, and, because of the high mixture-velocity, equal distribution to each cylinder is assured while starting. Further, the warming-up period automatically is reduced to the minimum, since the system is ready for operation as soon as the combustion-chamber reaches working temperature, which is a matter of importance from a maintenance viewpoint.

Since no heat is applied, the adaptation of cold carburetion is simple and affords a clean and relatively less expensive engine-design, and there are no passages that may become filled with carbon deposits as a result of heat.

Use of Kerosene as Fuel

Considerable experimental work has been done by the Delco Products Corp. with respect to the application of cold carburetion to automobile engines. It seems probable that in the future this system will receive the recognition it seems to deserve; but, even with cold carburetion, it is unlikely that fuels having an end-point beyond that of kerosene, namely, 625 deg. fahr., can be employed satisfactorily.

It is worthy of note that there are thousands of installations of electric-light plants in which kerosene is employed as fuel and cold carburetion is used; but these particular engines are of the nearly constant-speed type and their performance is directly comparable with that of the similar but larger engines used for gasoline-electric motorcoach propulsion. When consideration is given to the use of kerosene as fuel in internal-combustion engines, the fact should be remembered that this is a product having a flash-point above a certain legal minimum, which varies in different States but is about 120 deg. fahr.

The definition of kerosene given by the American Society for Testing Materials is: "A refined petroleum distillate having a flash-point now below 73 deg. fahr. and suitable for use as an illuminant when burned in a wick lamp." The United States Government master specifications for lubricants and liquid fuels, as prepared by the Federal Specification Board and issued by the Department of Commerce, Bureau of Mines, define the grade of kerosene ordinarily used by the Government and its agencies, including the Marine Service, as: "An illuminating oil, the end-point of which shall not be higher than 625 deg. fahr."

At present, the term kerosene does not cover a definite product, and specifications such as the foregoing are of too wide a range to permit determination of the suitability of any such fuels when used in connection with present-day heavy-duty motorcoach engines.

Summary

It already has been stated that numerous serious problems are presented by hot carburetion. These problems certainly have not yet been solved, and it is not believed that this system can be extended beyond the use of kerosenes and furnace oils. With cold carburetion we cannot expect to burn fuels that are outside of the kerosene ranges, but here again there are a number of unsolved problems. Consequently, assuming the necessity for burning the less volatile fuels, apparently the only practical solution is the Diesel engine and therefore no effort should be spared in connection with the full and complete investigation of this system.

It is not difficult to appreciate the troubles of the average operator who has daily before him unmistakable evidence of his rapidly mounting fuel bills; but unfortunately, no practical solution is in sight. From the viewpoint of the average operator, the problems involved are purely technical and, in addition, the inexorable laws of supply and demand must be taken into account. The point is that, although the selling prices of gasoline must be based on refining costs, such prices are purely arbitrary insofar as concerns their relation to the manufacture of gasoline, since they are computed while taking into account the market values of all the materials derived from the crudes. Consequently, if the present large demand for gasoline ceases, the selling prices of the kerosenes and gas-oils must necessarily be advanced; but, ignoring these laws and the subject of taxes and assuming that all of the problems concerning the use of the crudes, gas-oils and kerosenes were solved, the possible savings based on costs at the source would be, approximately, for kerosene, 0.5, for gas-oil 2.5, and for crude oil 3.95 cents per gal.

It has been mentioned that, for the purpose of this discussion, consideration is given only to costs at the source or well, since, in the last analysis, the handling charge must be identical regardless of the type of fuel. Obviously, the handling charges must include

the cost of bringing the oil to the refinery or dock; the tank-car freight, distribution and other costs are in addition.

As an illustration of actual selling prices, assuming the employment of gas-oil in place of gasoline, the wholesale or tank-wagon price of gasoline in Detroit is now 14.8 cents per gal. and the tax is 3 cents per gal., a wholesale cost[7] of 17.8 cents per gal. It has been shown that the basic difference in the respective manufacturing costs of gasoline and gas-oil is about 2.5 cents per gal.; so, assuming the general use of gas-oil instead of gasoline, it is logical to assume that the cost would be 15.3 cents per gal., which represents a saving of 14 per cent as compared with gasoline cost. In the final analysis, this is the real difference that can be expected. It is difficult, if not impossible, to forecast the price readjustments resulting from the use in a large way of gas-oil instead of gasoline; consequently this factor has been ignored. But it should be mentioned that there is no reason to suppose that there would be any reduction in the 14-per cent differential referred to.

As evidence of the uniformity of distributing costs, it is interesting to note that the refinery prices[8] of gasoline and kerosene are 6.75 cents per gal. for gasoline and 6.25 cents per gal. for kerosene; and the Detroit tank-wagon prices[9] are 14.8 cents per gal. for gasoline and 14.7 cents per gal. for kerosene.

As a result of an impartial analysis of the facts and data herein presented, it is difficult to escape the conclusion that any attempt to employ the less volatile fuels in place of gasoline will result in an immediate increase in the cost of such fuels. The important oil companies seem to be fully alive to this issue and, while perhaps a very limited number of motorcoach operators could purchase these fuels on a basis of their present selling prices, any such advantage could not possibly be permanent.

Briefly, when considering the crudes and their derivatives in the light of present knowledge, the available evidence points to the fact that we have no alternative other than to continue the use of our present fuel standard; namely, gasoline. There are, however, other fuels such as benzol and alcohol which may have an influence on our future activities; but such possibilities are not regarded as being within the scope of this discussion. It might also be mentioned that at present the production of these fuels is only relatively small, possibly around 2 or 3 per cent as compared with gasoline; and, while it is possible to produce both benzol and alcohol in large quantities, the production costs would be, in all probability, considerably in excess of present gasoline prices.

[7] See *National Petroleum News*, April 3, 1929, p. 124.

[8] See *Oil and Gas Journal*, March 14, 1929, p. 140.

[9] See *National Petroleum News*, April 3, 1929, p. 124.

The Demand for Nitrogen

AT THE outbreak of the World War the annual consumption of fixed nitrogen in agriculture amounted to roughly 550,000 short tons, of which about a third went to the United States. In 1928 the world produced about 2,000,000 short tons, of which the United States used 414,000 tons, including 300,000 tons as fertilizer and 114,000 tons for other industrial uses, such as refrigeration and the manufacture of nitric acid and explosives. Thus the consumption of nitrogenous fertilizers in the United States has increased fully 50 per cent within the last 15 years. In Central Europe it has increased several hundred per cent.

World Production of Fixed Nitrogen[1]

	1918	1928
	Short Tons	
Chilian Nitrate	488,000	539,000
Ammonium Sulphate from Coal	377,000	440,000
Synthetic Processes:		
Synthetic Ammonia	236,000	742,000
Cyanamide	198,000	243,000
Arc	33,000	33,000
Total	1,332,000	1.997,000

[1] From *Chemical Markets*, June, 1929.

The production of fixed nitrogen in Germany by all processes, in 1928, amounted to 735,000 tons, or more than a third of the world's total. About 86 per cent of this was synthetic. The United States produced only 186,000 tons, of which less than 26,000 tons was synthetic.

In France, Germany, and Holland the consumption of fixed nitrogen as plant food has more than doubled within 10 years. The United States uses only 1.2 lb. of fixed nitrogen each year for each acre of plowable land; France now uses 3.4 lb.; Germany, 12.6 lb.; and Holland, 17.1 lb. If the American consumption can be doubled—an increase of about 2 lb. of fixed nitrogen for each of 300,000,000 acres which it may pay to treat with fertilizers—we may still import as much fixed nitrogen as we do at present, yet find a market for three times the increased production due to new plants about to come into production in the United States. If domestic consumption is not increased, the new supplies must find an outlet through exportation or decreased importation.

Energy costs and fixed charges make up most of the cost of producing synthetic nitrogen. Since energy in many parts of America is very cheap, and capital is eagerly seeking outlet in the chemical industries, there is no reason why we should continue to derive from abroad so large a part of the nitrogen that is needed for our crops.—Arthur D. Little.

Application of Motor Transport to the Movement of Freight

By FREDERICK C. HORNER[1]

TRANSPORTATION MEETING PAPER[2] *Illustrated with* PHOTOGRAPHS AND DRAWINGS

AFTER defining the function of transport as the transfer of persons and things from one part of the earth's surface to another in the minimum time and at the minimum cost, and dividing modern transport into human, animal and mechanical, the author proceeds to describe the part played by commercial motor-vehicles in the Country's economic structure.

Since food and drink are necessities of life, the first examples of motor-truck transportation discussed include the haulage of milk, bakery products, livestock, produce, vegetables and fruit. These are followed by the use of the motor-truck in local and long-distance general hauling, retail delivery service of dry-goods and chain-store supplies, the oil industry and for the transportation of express matter. A section follows on the use made of this form of transportation by public utilities and municipalities. The coordination of railroad and highway transport is discussed at some length, the topics covered including store-door delivery, railroad-terminal trucking and a comparison of volume of freight handled by the railroad and the motor-truck.

In connection with the latter a table is presented showing that, for hauls of 39 miles or less in the vicinity of Cleveland, the motor-truck handles more than half of the freight moved but its efficiency gradually decreases with increasing distance until, for hauls of 100 or more miles, only 2.3 per cent is handled by the motor-vehicle. The saving amounting to $2,860 per month that was made by the Long Island Railroad through the substitution of one tractor and six trailers to eliminate the use of peddler railroad-cars is described, as is also a supplementary off-line freight service that has been developed by the Pennsylvania Railroad. Use of containers by the railroads for less-than-carload and for bulk freight is described, and a brief discussion of the use of the motor-truck in conjunction with airplane transportation follows. One or more illustrations of the vehicles used in various types of transportation discussed supplement the text.

In conclusion, the author points out that the movement of freight by motor transport is still in its infancy and the biggest problem is the application of this new transportation tool to present-day requirements, intensive and comprehensive use of the motor-truck in the short-haul areas of large cities and its coordination with the railroads. He does not feel that the extensive use of motor transport by the railroads, the full development of the container method and the universal establishment of store-door-delivery service will force the independent truck-operator out of business. Modern transportation facilities are a vital factor in the progress, security and comfort of every country, and the motor-vehicle, because of its inherent mobility and comparative low cost, has a most important place to fill.

THE function of transport may be described as the transfer of persons and things from one part of the earth's surface to another, in the minimum time and at the minimum cost. In recent years the vital importance of efficient transport to the progress of civilization has been more and more realized by the leading men in the world of commerce and politics. Without exaggeration we can say that the development of the wealth of any country has been brought about from time immemorial largely by the improvement in its methods of transportation.

In general, modern transport can be classified into human, animal and mechanical. In its various forms the last is carried on by land, road, sea, canal, river, lake, railway, air, and aerial ropeways. The form I will deal with is road transport of the mechanical type in which the internal-combustion engine provides the motive power and specifically motor transport; that is, the use of commercial motor-vehicles as distinguished from the automobile in the general sense of the word.

The first motor-truck, or motor lorry as the English call it, was a converted automobile or motor-car, perhaps rebuilt by a blacksmith, or a crudely constructed affair with a heavier axle and springs and perhaps with strengthened frame. The evolution from that type of commercial motor-vehicle to the present-day truck and truck-tractor vehicles that carry 3 to 5 tons of freight at high speeds and the heavy-duty type of tractors which move from 7 to as high as 50 tons with semi and four-wheel trailers represents a mile-post of progress in the use of motor transport that, to the initiated, is as interesting as it is creditable to those who have made it possible.

Taking them in the order of their importance to humanity and the exchange of goods, examples of motor-truck transportation will include the haulage of milk, bakery products, livestock, vegetables and fruit, general merchandise, retail delivery-service and express matter, as representative of the more important specific classifications. In addition, the general trucking field will be covered with special reference to the use of trucks by our large public utilities, municipalities, and State highway departments, including the application of special equipment and special classes of motor haulage, such as containers and rail-terminal trucking, as a part of the coordination of rail and road transport facilities.

Food and drink are the vital essentials of life and when a transportation facility has reached that stage of

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[2] Also presented at the World Engineering Congress, Tokio, Japan, Oct. 29 to Nov. 7, 1929.

perfection in which we can depend on it to bring us our daily milk, bread and meat, little question can be raised regarding its reliability. In the great English railroad-labor strike in 1919, motor transport was mobilized and operated by Army methods and the babies and the sick first, and then the people as a whole in the cities, were kept from privation or actual starvation.

The Transportation of Milk

The problem of the haulage of milk has reached tremendous proportions, with the ever-increasing population of our large cities and the shifting and emigration from small towns and country districts, and speed and efficient handling are imperative in the transportation of this perishable commodity. As far back as 1924 the motor-truck began to take over the bulk shipments formerly handled by the electric railway and horse-drawn vehicles and now is taking a large part of the steam-railroad short-haul shipments. This is largely accounted for by the gradual crowding back of the dairy farm, the growth of city suburban areas and the general evolution of both rail and road transportation methods. Some of the advantages of motor transport are: The truck passes the producer's farm, or community roadside platform, and the truck driver acts as a personal agent of the farmer in the country and also in the city. Shipment by truck reduces the number of handlings from six or more to only two. In the past, when the farmer delivered his milk cans to the station and received a receipt, the steam railroad delivered them to its freight yard and the city milk dealer had to call and collect the cans to enable him to rebottle and pasteurize the milk before delivery. The return trip of empty milk cans presented the same problem, and considerable loss from handling them was eliminated by the door-to-door transportation of the motor-truck. The loss in rail transport of milk cans and the elimination of the haul from railroad milk platform to the city milk dealer result in an estimated saving of about 5 cents per 100 lb.

Figures compiled by the National Automobile Chamber of Commerce show that milk transportation by truck has increased with tremendous strides. Approximately 90 per cent of all milk brought into the cities of Cincinnati, Indianapolis, Detroit, Milwaukee, St. Paul and Minneapolis is hauled by motor-truck. About 20 per cent of all milk used in Philadelphia and Baltimore is handled by motorized transportation. Of trucks handling milk in these cities, 65 per cent operate within a radius of 20 miles and about 10 per cent operate on routes of 50 miles or longer. In the 30 to 40-mile zone, 20 cents per ton-mile is generally charged, while for longer distances the rates are slightly higher. A comparison of rail and motor-truck costs for hauling milk shows that, taken as a whole, truck rates are somewhat lower owing to the more flexible movement and the door-to-door delivery feature.

Transportation of milk in bulk has developed the tank truck. The glass-lined tank truck, shown in Fig. 5, possesses great advantages for hauling milk from country stations to city plants, especially where neither are located directly on the railroad, and when the distance is not beyond the economic range of the truck. The capacities of these tanks range from 500 to 2000 gal. According to statistics gathered by the National Automobile Chamber of Commerce, 20 per cent of all the large companies in our metropolitan cities have milk-delivery stations strategically located according to density of population and distribute their quota with fleets of trucks, using both gasoline and electric vehicles, and the customers have their milk delivered each morning regardless of weather conditions. The use of truck-tractors and semi-trailers facilitates the unloading and handling of bulk shipments of bottled milk. To preserve an even temperature, the bodies are specially built and insulated and remain sealed until opened at icing station or final delivery points.

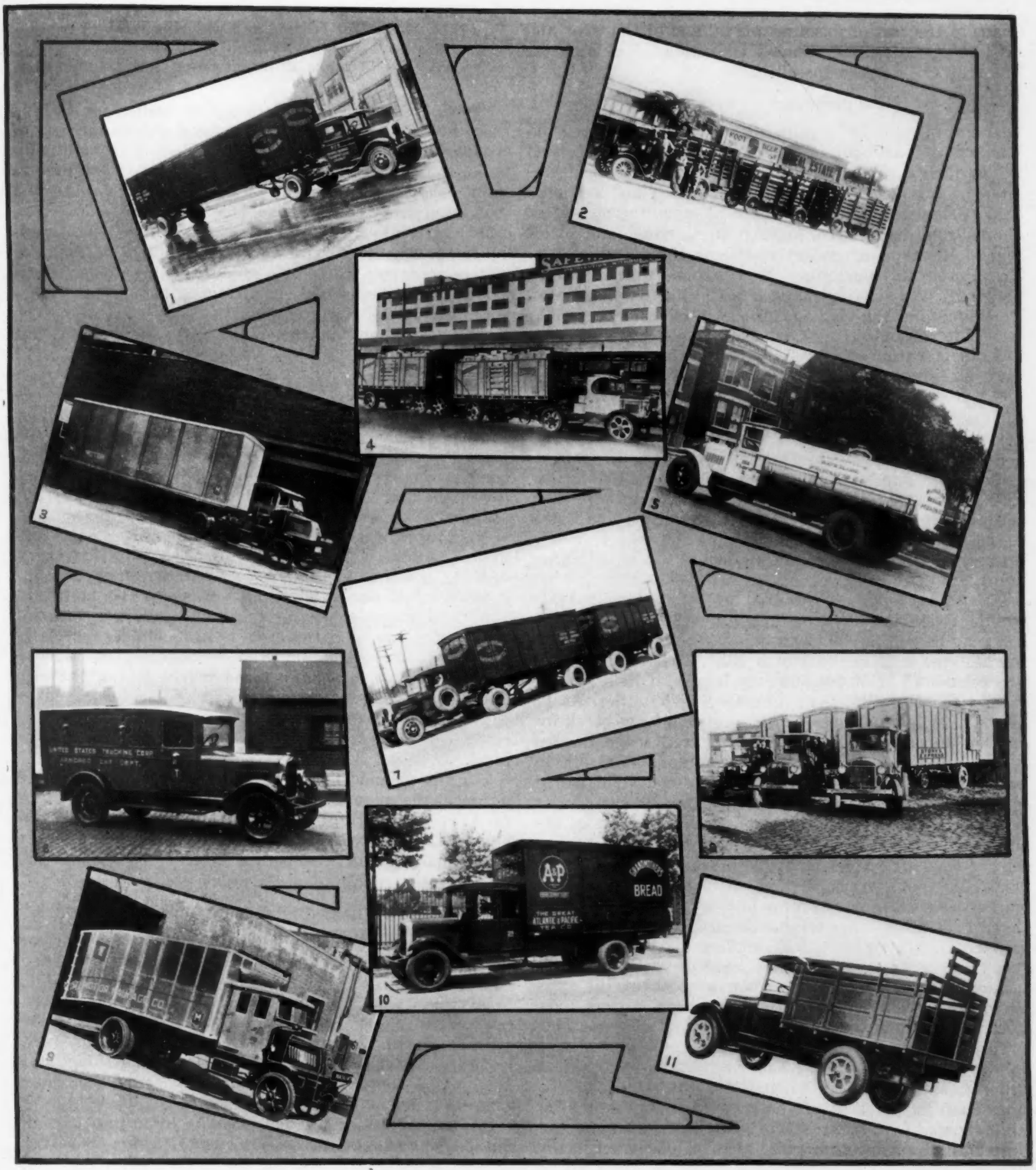
Transportation of Bakery Products

A recent survey of the bakery field in the United States shows that more than 65 per cent of all retail delivery service is handled by gasoline trucks, 18 per cent by electric trucks and the remaining 17 per cent by horse-drawn vehicles. The relative efficiency of the three classes of vehicle is shown by the fact that 2200 lb. is being delivered per route-day by gasoline truck, 1500 lb. by electric truck, and 700 lb. by horse-drawn vehicle, covering daily routes that vary from 18 to 35 miles. Several kinds of operating requirements must be met in this work. The range of activity of the horse and wagon is limited to an average of 18 miles per day. The electric truck averages between 27 and 28 miles per day but is not well adapted to winter climates because of the danger of freezing batteries and connections, thus reducing its field of usefulness. The gasoline-driven truck leads the field by giving complete service the year round and averaging from 30 to 50 miles per day in all weather conditions. More than two-thirds of the trucks used in this industry are in the medium-price class. According to the latest figures, more than 35,000 trucks are in use by bakeries, 16,000 having a capacity of 1 or 2 tons, 5000 from 2 to $2\frac{1}{2}$ tons, and the remainder ranging upward to 5 and $7\frac{1}{2}$ tons.

Several types of body are in standard use in the large bakery fleets, one being shown in Fig. 10. The use of trailers and semi-trailers in this class of service has come into prominence within the last few years to transport bulk loads from central warehouses and large bakeries to the local stores and delivery points for house-to-house delivery. The days of the local bakery shop, in which all work is done on the premises, are becoming a thing of the past, and the bread business, like the milk industry, has become highly specialized and compels the use of highly efficient types of vehicle and body to market the vast quantity of foodstuffs necessary to feed cities of millions of people. In the operations of these large fleets, service plays an important part in keeping the vehicles on the road. Spare units, such as engines, transmissions, axles, differentials, and other essential parts of the vehicle, are kept in reserve at all times. Economy of operation is based, not only on the mileage given by the truck, but complete cost records are kept of each type and make of vehicle to determine which will best answer the purpose.

Large fleet owners operate their own paint shops in which the vehicles are periodically placed for painting. Experience has proved to more than one business man that a shabby, run-down truck will not attract business as will a clean, brightly painted vehicle with a uniformed driver. This is especially true in house-to-house delivery work.

Where stopping and starting of the vehicle are almost continuous and the driver must be a salesman as well, the bakery companies have equipped their trucks with self-starters to lessen the cost of operation. Surveys



SOME APPLICATIONS OF THE MOTOR-TRUCK IN FREIGHT HAULAGE

Fig. 1—Tractor and Trailer Used in Long-Distance Service and Capable of Carrying the Same Bulk as a Standard Freight Car. Fig. 2—Truck and Trailers Hauling Live-Stock. Fig. 3—Duralumin Trailer-Body Which Has Been in 24-Hr. Service Daily for Three Years without Painting or Repairing. Fig. 4—Tractor Semi and Four-Wheel-Trailer Combination Equipped with Air-Brakes and Capable of Carrying Loads up to 40 Tons. Fig. 5—Hermetically Sealed Glass-Lined Insulated Tank-Truck for Hauling Milk. Fig. 6—Armored Car with Side Turrets for Guns and a Cab with Bullet-Proof Glass Used for Transporting Money. Fig. 7—Tractor Semi and Four-Wheel-Trailer Combination Having a Capacity of 1½ Freight Cars. Fig. 8—A Fleet of Tractors and Semi-Trailers in the Coordinated Rail and Road Service of the Boston & Maine Railroad. Fig. 9—Motor-Truck with Armor-Plate Steel Cab and Bullet-Proof Glass and Duralumin Body for Transporting Valuable Merchandise. Fig. 10—Another Example, Used in Delivering Bakery Products, of a Motor-Truck with a Duralumin Body That Is Very Light in Weight but Strong as Oak and Steel and Easily Repaired and Maintained. Fig. 11—The Type of Rack-Truck with High-Side Body and Sliding Tail-Gate Used by Farmers for Hauling Hogs, Sheep, Apples, Grain and Truck-Farm Produce

made of the cost of gasoline and oil and of the wear and tear of operating parts show a considerable saving after the starter has been installed.

Transportation of Live-Stock

A commission of inquiry of the United States Government Department of Agriculture made an extended study during 1928 of the influence of motor transportation on farm costs and live-stock prices and reported that perhaps no single development since the advent of the railroad had had so marked an economic and sociological effect upon productive life as the motor-vehicle. Previous to its appearance, the economic zone of transportation was sharply defined by the haulage range of the horse and the cost of this form of transportation, with due reference to loss of time involved.

Transportation of live-stock to terminal markets has always been a matter of concern to farmers, more especially to those who raise live-stock on a relatively small scale as part of the regular agricultural pursuits. When dependent upon rail service, the farmer could ship economically only at times when enough stock to make a carload was available. Now, through the radio, he receives market quotations daily, and in a very short time can prepare his stock for shipment by truck and drive to market in about the same time as was formerly ordinarily required to reach his local railroad shipping point.

According to figures secured by the National Automobile Chamber of Commerce for 1928, motor-trucks last year hauled 12,000,000 head of live-stock, representing a 46-per cent increase over 1927. The truck mileage was estimated at 50,000,000; the length of haul ranged from 1 to 300 miles, the average being 50 miles. At 11 of the principal markets, truck receipts of live-stock increased 40 per cent over 1927, and at Chicago the increase was 112 per cent. Three and one-half million head of hogs were shipped by truck to 15 principal markets in the United States, this being almost 15 per cent of the total receipts. In addition, 5 per cent of the sheep, more than 12 per cent of the calves and 4.5 per cent of the cattle received at these markets were transported by motor-truck. Usually live-stock is hauled to market by operators owning one or more trucks engaged in hauling other commodities. The small operator with possibly a single truck handling six to eight hogs at a time, or from four to five head of cattle, and the farmer hauling his own stock on a truck of the type shown in Fig. 11 represent the two main classes of live-stock motor-transport operators.

Figures recently compiled show that in one metropolitan center from 1913, when the receipts were 90,000 animals, until last year when they were over 800,000, more than 90 per cent of the live-stock was hauled by motor-truck. Live-stock receipts at stockyards in the United States show that more than 47,000 truck loads of animals were hauled within a range of from 40 to 80 miles from the central delivery point. Units of from 2 to 5 tons' capacity fitted with bodies of the rack type and from 12 to 20 ft. long, as shown in Fig. 2, are the type of equipment used in this service. Some of the great advantages of the motor-truck in the transportation of live-stock are

(1) A minimum of shrinkage
(2) Swift delivery
(3) Ability to take advantage of favorable market prices
(4) Less cost for feeding and watering stock in transit
(5) Ability to make shipments of a few animals at one time

During the last few years roll-off bodies for feeding hogs at farms have come into general use. In the City of Omaha all the refuse formerly collected from wagons and freight cars by the scoop shovel or forking process is now collected by the roll-off body system. This system not only saves considerable labor but also only a few hours elapse between collection and delivery, which enables the farmer to receive a fresh supply of food for his hogs daily. By means of a traveling winch these bodies are rolled from car to truck, so that the truckman can deliver his load with the body and call on the return trip to pick up the empty body, saving both time and labor.

Transportation of Vegetables and Fruits

As is common practice in all countries, the perishable produce markets operate in the early morning hours. Motor-trucks serve them in two distinct ways; first, they are used to haul between farm and market place direct, and, second, to haul between rail produce-yard and market place and retail green-grocer store.

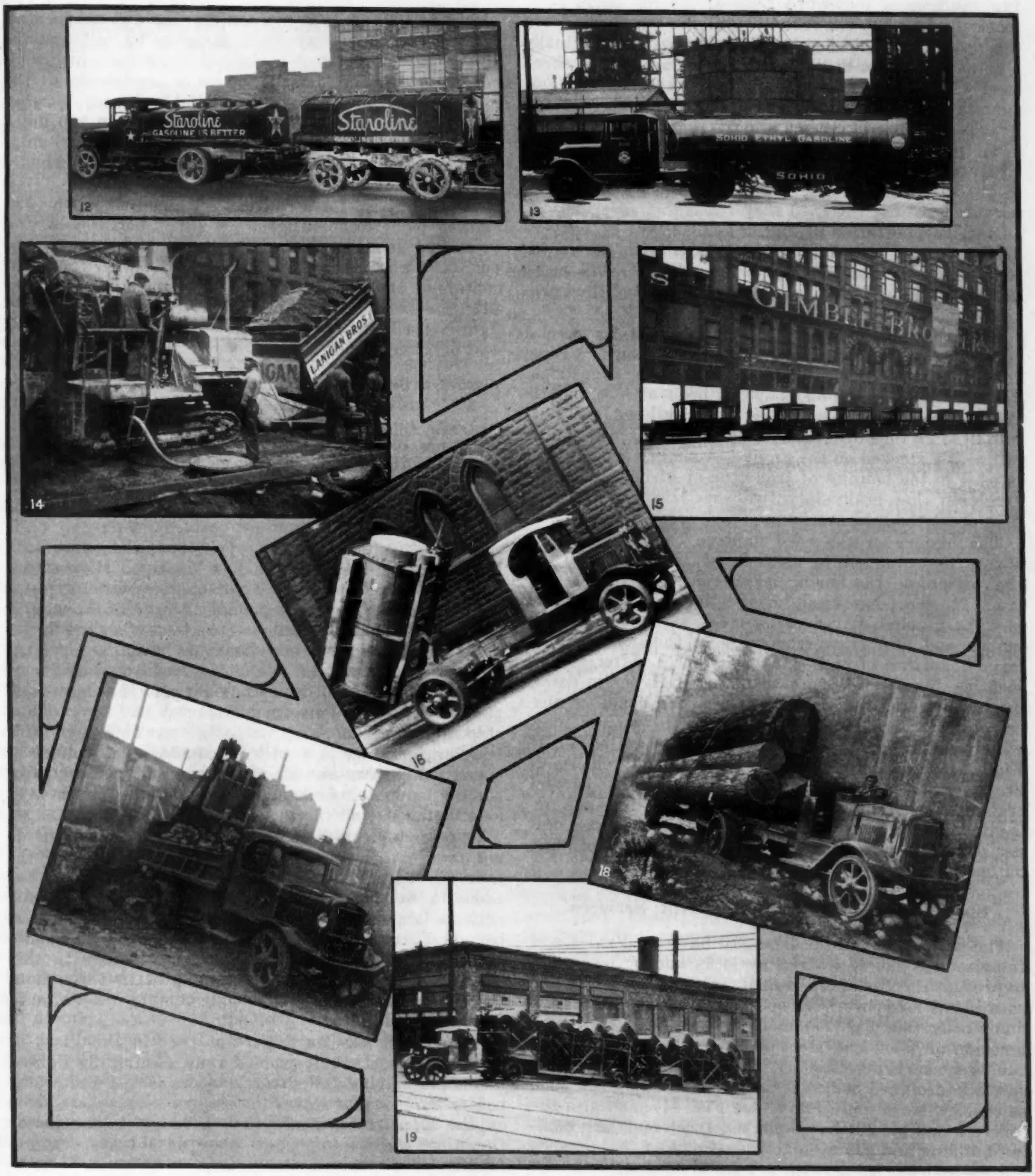
Probably the greatest economy and convenience furnished by motor transport in this class of haulage is in hauling perishable produce between metropolitan railroad-terminal and suburban areas. Here the saving in time and expense due to moving cars from railroad transfer points to these areas is incalculable, especially in hot weather when the produce deteriorates and decays so rapidly. The high-speed truck leaving the city produce-terminal between midnight and 3:00 a.m. makes delivery at suburban markets in ample time to be ready for retail and local wholesale buying that morning.

For the transportation of vegetables, fruit and other produce, the general-use body is of the platform high-rack type, averaging in length from 15 to 22 ft. and in height from 6 to 8 ft., and constructed with slight "camel back," that is, sloped off from 1 to 1½ ft. in the rear to make loading and unloading easier.

Local and Long-Distance General Hauling

Short-haul trucking predominates; the major part of the tonnage transported by motor-truck moves less than 30 miles. Figures from surveys by the Bureau of Public Roads show that in five of our most important States, from 60 to 80 per cent of the hauls are less than 30 miles and only 3 per cent are 100 miles and over. Analysis of available cost-figures shows that long-haul trucking is generally unprofitable, whereas the short haul, 45 miles or less, is profitable.

The proper design of body plays an important part in the securing of business by our large truckers operating in metropolitan centers, as the diversified loads and demands of hauling different commodities preclude the use of any one standard type of body. Transportation has advanced in economy and efficiency in proportion to the intelligent application of human endeavor and capital investment. Large operators have specialized in certain lines of haulage. We have the Armored Car Co. operating fleets of armored cars of the type shown in Fig. 6 for handling valuable merchandise and transporting securities and money. These units are mounted on high-speed truck chassis and equipped with doors hav-



TYPICAL EXAMPLES OF SPECIAL MOTOR-TRUCK BODIES FOR SPECIFIC INDUSTRIES

Fig. 12—Motor-Truck and Trailer, the Latter Equipped with Air-Brakes, Hauling Gasoline. Fig. 13—Tractor and Semi-Trailer Equipment for Transporting Oil, the Front of the Tank on the Trailer Being Curved To Fit the Turning Radius. Fig. 14—Dump-Body Motor-Truck Used in Connection with a Batch-Mixing Machine for Concrete. Fig. 15—Fleet of a Large Department Store, the Individual Vehicles Being Equipped with Screen Sides To Prevent Theft While Providing Air for Perishable Merchandise. Fig. 16—An Example of How Time Is Saved in Building Construction; a Ready-Mixed Concrete and Plaster Batch Motor-Truck Body. Fig. 17—Automatic Dump-Body Motor-Truck Used in Excavating and Building Work. Fig. 18—A 5-Ton Tractor and Trailer Unit Used by a Logging Company Where the Roads Are None too Good. Fig. 19—The Use of a Tractor and Trailers Results in a Large Saving in Time and Transportation Charges in Delivering Automobiles

ing windows of bullet-proof glass; the cab doors automatically lock the chaffeur in until the rear body-doors are opened, so robberies in this field have been virtually eliminated. These bodies are made of heavy-gage sheet steel which will withstand rifle fire, while machine-gun turrets are mounted on the sides of the bodies for guards to utilize in case of attack.

To prevent robbery in the haulage of cigars and cigarettes, a special metal body of the type illustrated in Fig. 9 is used. These bodies are locked with strong bars and not opened until they reach their destination. In the transportation of silk, a similar type of body is used, mounted on a high-speed chassis with automatic locking device which, when tampered with, will automatically shut off all power in the engine and thus prevent bandits from driving off with the truck.

Almost every line of business demands its special type of body, two examples of which are shown in Figs. 18 and 19; thus, in the lumber and iron-pipe industries, use is made of a roll-off body equipped with automatic rollers which, from a slight leverage by hand, will permit 10 to 20 tons of lumber to slide off the truck and be left neatly stacked on the ground. A similar type of unit is used in the hauling of iron pipe or girders, with the exception that heavy-duty two-wheel trailers are used to support the load overhang.

The history of the road haulage business shows a steady improvement in methods of transportation: in the beginning, the horse and wagon, then the electric truck for short hauls and house-to-house deliveries, and last the gasoline-driven motor-truck as being the most mobile and also most economical method of handling large quantities of freight long distances. After experimenting for several years with various types to determine which was the most economical for handling miscellaneous freight, tests show that, with two and four-wheel trailers, and tractor units such as are shown in Figs. 1, 3, 4 and 7, the idle time of the vehicles is greatly reduced by having one tractor serve several trailers. For example, with one trailer loading, one unloading and one in transit, the traffic moved per unit per day is increased from two to five fold, depending on operating conditions encountered.

Special Body Types for Different Services

The majority of the bodies used have solid sides and full-size rear doors secured by locks and/or lead seals to prevent theft while in transit. In the contracting and excavating fields we have specialized on the automatic dump-body (see Fig. 17) made of sheet steel or a combination of wood and steel and rated according to the cubic-foot carrying capacity. In common use today are specially designed bodies to accommodate material such as cement, stone and gravel (see Fig. 14), and also the concrete and plaster batch-method truck-body for hauling building and paving materials. Some of these bodies are made drum shape with a gear arrangement driven from the power-take-off device that turns the drum or body as the vehicle moves (see Fig. 16), thus keeping the concrete or plaster thoroughly mixed and ready for immediate use upon arrival at destination. The capacity of any regular dump-body can be increased by the use of steel or wood side-boards.

Furniture and household goods constitute a class of freight that can be moved economically by truck over the highways and for greater distances than almost any other freight. The length of haul ranges from a few blocks to 1000 or even more miles. The absence of crating expense, necessary when shipping by rail, and the service being from door to door, with complete insurance covering loss and damage, gives a preference to the most flexible unit, the truck. Reliable figures showing the difference in cost of removal from 25 to 100 miles are in favor of the motor van, while on long-haul shipments of more than 500 miles, the rates are usually slightly in favor of rail movement.

Table 1 gives, for a railroad serving Boston, the distances to certain stations, the tariff per 100 lb. for household goods with responsibility limited to 10 cents per lb., the railroad charge for 5000 lb. with 750 lb. of container, and the total cost of moving goods, including $125 for packing, handling and local hauling. The truck figures used are based on an empty return trip at a cost of 25 cents per mile.

TABLE 1—COMPARISON OF RAILROAD AND TRUCK CHARGES FOR MOVING HOUSEHOLD GOODS

Distance, miles	44	98	150	200	294
Tariff per 100 Lb., cents	47½	58½	63½	63½	72½
Tariff on 5,750 Lb.	$27.31	$33.64	$36.51	$36.51	$41.69
Total Cost	152.31	158.64	161.51	161.51	166.69
Long-Distance Truck Charges	42.00	75.00	106.50	138.00	195.00

Improvements in design of both chassis and body have revolutionized this class of haulage. High-speed, long-wheelbase, pneumatic-tired chassis with plymetal fully enclosed van bodies padded to prevent damage in transit, fully closed vestibule cabs to protect the driver and helpers, and other improvements have brought long-distance motor haulage to a high standard of efficiency.

Another type of body used in transporting high-class merchandise over long road distances and by rail and ship is the lift-off body or container. This removable body or container is used by a considerable number of overseas shippers and English firms engaged in transporting valuable merchandise and household goods over long distances and through several countries.

In cases of long-distance haulage where the loads do not require the service of two trucks, the use of the four-wheel trailer, carrying one-half the total load, has added to the load efficiency of the vehicle. The additional expense is comparatively small and, if the movement is beyond 50 or 75 miles, the increased load adds substantially to the revenue. The use of trailers in this class of service has become common practice throughout the United States and is gradually coming into vogue in European countries.

Body types play an important part in this class of motor transport. Fully padded vans, electrically lighted inside and having full-size rear-doors locked and sealed before the operator leaves the shipper's house, are some of the latest refinements that have given the motor furniture van its important place as a transportation facility.

Other examples of long-distance trucking can be found in daily use between all of our large cities and important towns throughout the whole Country. Of course, the high-class merchandise is what moves by truck, and more prompt delivery service usually is the reason why the merchant ships by truck instead of rail. Goods picked up at the store door up to 5 and even 6 p.m. are delivered before noon the following day 100 miles away. In most instances, trucks in this service

obtain part or full return loads and thus the rate by truck, including the store-door-delivery feature, is usually very close to the rail rate on high-class goods. This field for the truck will continue to grow until the railroads establish store-door-delivery service. Typical tractor-trailer combinations for this service are illustrated in Figs. 1 and 7.

Dry-Goods and Retail-Delivery Hauling

With the ever-increasing popularity of the automobile bringing people into the large cities to do their shopping, and the building of good roads at the rate of 35,000 miles per year, all affecting suburban rail service, the large department stores have been forced to operate large fleets of gasoline and electric vehicles to serve their army of customers. This to a very large extent has been made necessary by the modern woman who does not desire to carry anything home, not even very small articles. Therefore, the retail stores were compelled to meet competition by increasing their free-delivery radius until today a daily service within a radius of 75 miles of the metropolitan cities is very common.

Taking a representative example of the receipt and distribution of merchandise each day by a large metropolitan department store, we find that in one day's business 105,000 packages of various descriptions are moving outward and 487 vehicles handle these packages. For the short-haul small-parcel deliveries within a radius of 30 miles, 86 electric vehicles are used. This store operates, outside of its own garage and maintenance department, seven remote depot-stations where all merchandise purchased in the store by 4 p.m. is delivered to the depots the same day to be re-sorted, reclassified and sent out to the respective zones by light vehicles for delivery to customers the following morning. It operates fleets of vehicles of various sizes with capacities and types of body to suit all conditions, from the small high-speed panel-body truck for small packages (see Fig. 15), to the 5-ton van-body truck hauling a trailer to handle bulk merchandise from store to depot warehouse. The operations are under the direction of a superintendent of transportation, with an efficiency engineer in charge of dispatching all vehicles. In the case of bulky merchandise, such as furniture, refrigerators and similar articles, only samples are kept on display in the store, delivery being made from warehouses situated in outlying sections of the city and having adequate railroad-track facilities for receiving and shipping by rail. A record chart of all vehicles is kept so that the dispatcher knows where every one is operating.

Drivers perform an important part in this delivery service, especially in cases of collection on delivery, commonly known as C.O.D. They are intrusted with thousands of dollars in cash and merchandise, and consequently great care must be used in their selection. Accidents are a serious factor in operating trucks in crowded streets. One large department store inaugurated a safety campaign and used the following procedure to educate employes:

(1) Weekly meetings with drivers were held
(2) Addresses by efficiency engineers on careful operation of trucks
(3) A bonus payment of $5 to each driver for every consecutive seven days of driving without an accident
(4) Large posters and signs asking help in this safety campaign were placed on the vehicles and blackboard talks were given on proper driving-methods, such as caution at intersecting streets, watching for school children and the like.

In 1000 vehicle-days, accidents were reduced to 12 per cent of the number in the previous period. Each of the vehicles covered more than 100 miles daily.

For short hauls in congested districts or where stops are frequent on house-to-house deliveries, the electric truck is used and has proved to be very economical in operation for this class of work. In hauling bulk merchandise from the central delivery-point to the remote depot-station, trailers and semi-trailers are used, as the time lost in waiting to be loaded is utilized by the tractor in hauling loads to other depots.

Motor Transportation in the Oil Industry

As the United States ranks first in the production of automobiles and motor-trucks, with a registration in 1928 of more than 24,496,000 units, one of our major transportation problems is to keep these vehicles supplied with oil and gasoline. With the production of gasoline and oil ranking fourth in our national industries and sales of this commodity for 1928 being in the neighborhood of $2,400,000,000, a vast organization is needed to supply the ultimate consumer, the motorist. To service this great array of motor-vehicles, oil companies operate more than 38,000 trucks hauling bulk gasoline and oil to retail service-stations situated strategically about the Country.

Beginning with the source of supply, the oil fields, we find that the motor-truck is first on the ground where an oil well is to be driven. Timber and drilling apparatus for wells, nitroglycerin and powder to "shoot" the wells, and other supplies of all kinds must be transported. Invariably the roads are either bad or are mere trails across field or prairie, and this had much to do with developing the pneumatic-tired motor-truck for heavy high-speed hauling. Overloading and overspeeding are common practices with truck operators and oil companies in the oil fields, but speed is of paramount importance when an oil "strike" is made and thus the excessive cost of transportation sinks to insignificance beside the advantages gained.

As the bulk of our gasoline and oil is produced in the southwest portion of the United States, railroads hauled in excess of 2,000,000 cars of gasoline, oil and oil products in 1928 to various parts of the Country for distribution. When one of these cars arrives at a local depot, the contents is pumped into a large reservoir-tank for use in that zone or locality. Tank trucks then distribute oil and gasoline within a radius of 75 to 100 miles of the source of supply. To transport gasoline, kerosene and other inflammable products in large cities, operating tank trucks of the types shown in Figs. 12 and 13, that have been approved by the Board of Fire Underwriters, becomes necessary. These tanks are built with separate compartments holding from 200 to 500 gal. each, with a total carrying capacity of from 1000 to 2000 gal. The compartments are automatically closed and controlled by an electric lock in the driver's cab, which seals the ignition before the truck leaves the delivery station, and no one can gain access to the gaso-

line pipes or the bucket box until the driver opens the lock in his cab.

Express Motor-Transport

Some of our largest fleet owners are express companies, and they have in service more than 10,000 vehicles of various descriptions, from small electric trucks used for local delivery within a radius of 10 to 20 miles, to heavy-duty 5-ton units, capable of hauling one or two trailers carrying from 10 to 35 tons of merchandise. Starting years ago with the horse and wagon and finding these unsuitable for heavy and long-distance deliveries, the express companies adopted the electric truck, which is used for short-haul local deliveries, and then the gasoline-powered truck for heavy-duty service and the long-haul movement of bulk merchandise.

As our express companies are closely allied with the railroads, one of their biggest problems is their limited terminal capacity; congested terminals cause embargoes, with the resultant shipping delays and confusion. The motor-truck is now truly indispensable for terminal service. Through its use the time of transit, loading and unloading and the handling costs are reduced, and equipment for line-haul movement is released more promptly. To meet the terminal problem more adequately, using motor-trucks was a step forward, but it did not fully meet the requirements in handling solid loads of express matter economically because the power unit was idle during the period of loading and unloading. This situation caused investigations of the possibilities of tractors and trailers and after considerable study the express companies decided upon a semi-trailer type as being best suited to their needs. The faster operation of the trailers made it possible in many cases to provide a direct movement from express car to trailer. In operating the tractor-trailer unit, the loading and unloading of trailers is performed by terminal forces, except in cases of delivery to large individual receivers where this is done by the driver and helper. For the efficient operation of this equipment the proper ratio between the loaded and empty moves must be maintained. Experience has shown that approximately 65 per cent of the total moves of trailers are loaded ones.

The advantages to the express companies of this type of equipment may be summarized as follows:

(1) One tractor serves for three smaller units, and each unit has double the ordinary express-vehicle capacity
(2) Uninterrupted loading due to availability of semi-trailers
(3) Saving of valuable terminal platform-space because of the available loading space provided by the semi-trailers
(4) Elimination of waiting time of chauffeurs for the preparation of loads
(5) Constant intensive use of the principal part of the investment, the tractor, which is not idle during loading or unloading of the trailer

While tractor and trailer equipment is not adaptable to all cartage problems, the majority of the express companies today use this method of hauling bulk merchandise.

Special Vehicles Used by Public Utilities

Among the largest users of motor-trucks in the United States are the public-utility companies, the largest of which is the American Telephone & Telegraph Co. Recent figures compiled show that more than 13,000 vehicles of various capacities are in use by our telephone companies, and over 17,000 units by the gas and electric companies.

The majority of these trucks are equipped with special types of body, such as the ambulance capable of a speed in excess of 60 m.p.h., and the slow truck-tractor with pole-setting equipment designed to travel at not more than 15 m.p.h. Line construction and repair work play an important part in the usage and design of a great part of these fleets. Bodies equipped for performing all emergency work necessary at a great distance from the base of supply operate in zones based on density of population. Emergency crews are thus able to set poles quickly, make repairs and install new lines to replace those damaged by wind storms, floods, snow, and ice through the use of vehicles similar to that shown in Fig. 22. Special post-hole diggers equipped with rock-drills and air-compressors mounted on high-speed trucks, one of which is illustrated in Fig. 21, greatly facilitate opening up concrete or macadam streets in record time for underground cable or conduit work.

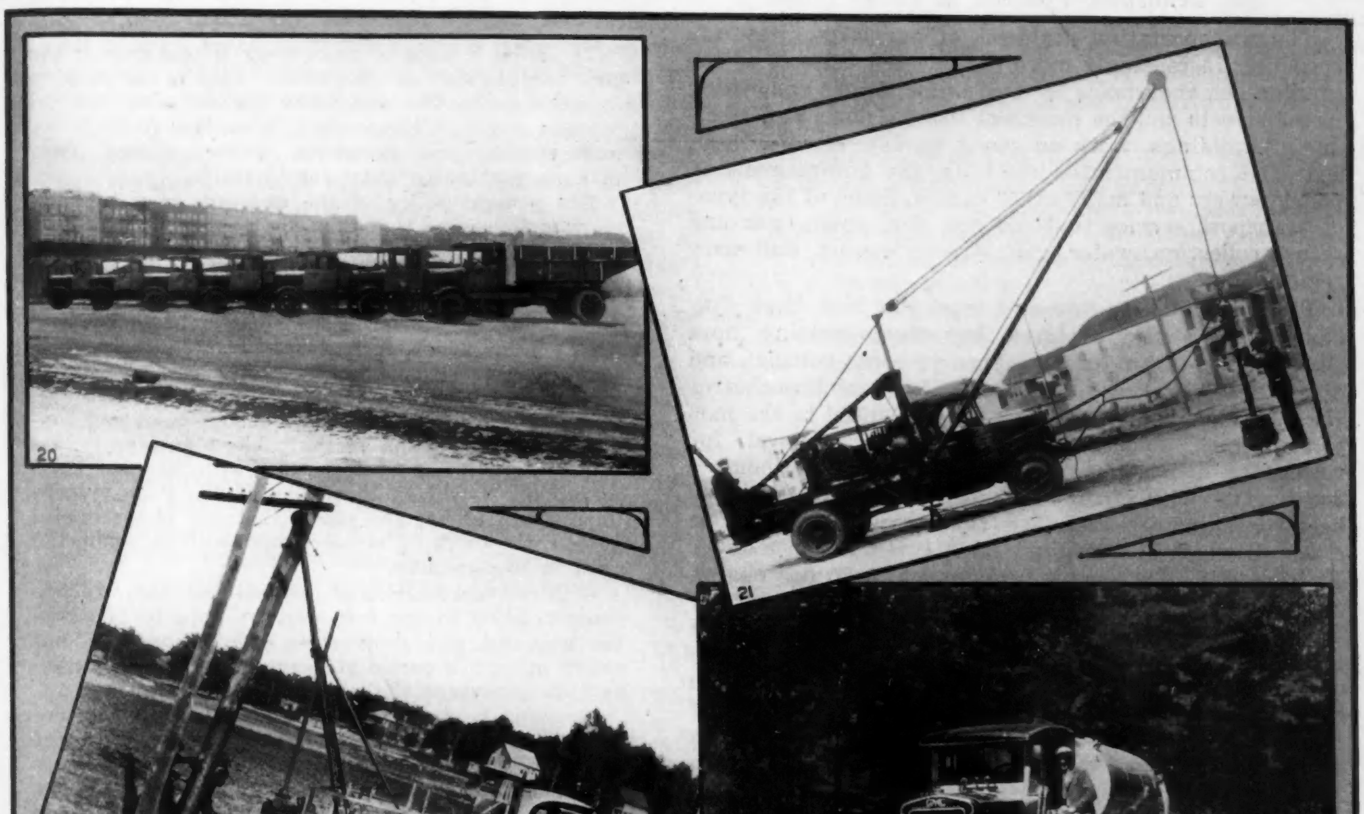
Auxiliary Power-Operated Devices

In different departments of public-utility companies, motor-vehicle equipment is of prime importance from a purely transportation standpoint. To make the most intensive use of the motor-truck to assist the various functions of linemen, underground workers, maintenance departments and local installation divisions, proper mechanical means must be provided to assure speedy and accurate work and to minimize accidents.

The power winch is one of the most useful devices for public-utility service. It is driven from the motor-truck engine and is capable of pulling 10,000 lb. on a steel-wire rope or cable. Numerous uses are made of the power winch, such as

(1) Pulling telephone cables into conduit
(2) Erecting poles with derricks
(3) Handling all kinds of loads on and off trucks
(4) Loading reels of cable on trailers and other vehicles

When street pavements have to be opened in connection with underground conduit construction, and where rock has to be blasted, gasoline-engine-driven air-compressors mounted on motor-trucks provide the maximum flexibility of operation. These trucks carry the compressed-air drills and necessary equipment as well as the operators. Boring machines and equipment for digging holes and power-winch-operated pole-derricks have been developed. All this equipment is driven from the motor-truck engine. Where the digging of a hole and the erection of a pole might ordinarily require several hours of hard work, the motor-vehicle with its power equipment makes possible the doing of the work in a few minutes. As motor-vehicles are gradually being developed to perform the transportation function more efficiently, close cooperation exists between the users of these vehicles and the manufacturers. Two-wheel pipe or pole trailers have come into common use by the telephone company. These are capable of handling telephone poles from 20 to 45 ft. long and can be attached to the rear of the truck to carry the poles long distances for installation on the highways and at inacessible places.



TYPES OF MOTOR-TRUCKS USED IN PUBLIC-UTILITIES AND MUNICIPAL SERVICE

Fig. 20—A Fleet of Garbage Trucks Equipped with Steel Bodies and Folding Doors That Cover All Refuse and Yet Facilitate Cleaning and Washing the Bodies. Fig. 21—Motor-Truck Equipped with Compressed-Air Post-Hole Digger. The Truck Can Operate Five Rock-Drills Simultaneously within a 30-Ft. Radius. Fig. 22—A Public-Utility Company Truck Which Is Specially Equipped To Set Poles and Repair and Maintain Telephone Equipment. Fig. 23—Street Sprinklers Similar to This Which Has a 2000-Gal. Tank and Can Spread Water 50 Ft. under Pressure, Perform an Important Part in Keeping Cities Clean. Fig. 24—A Fire Department Motor-Truck That Is Completely Equipped with Chemicals and a Pumping Engine. Fig. 25—A Motorized Snow-Plow That Plays an Important Part in Keeping City Streets Open for Traffic in the Winter.

The Transport Problem in Large Cities

The transportation problems of our large cities are becoming increasingly more complicated because of the greater demands made by the public, traffic congestion in the streets and the incessant tearing down and erecting of buildings, work on street paving, sewers, light, heat and communication conduits, the enforcement of police powers and many other causes. Some of the types of transport service involved are, fire, police, ash and refuse collection, water, gas, street cleaning, and snow removal.

The municipal operation of trucks in New York City has become a vast problem. Any city operating more than 4000 units of various types presents complex and diversified operating problems. In different branches of the municipal service we have trucks suited to the particular work, such as garbage and ash removal, for which the bodies used are of the all-steel automatic-dump type with covers that completely close and so keep odors and dirt and dust from escaping. The trucks, a fleet of which is shown in Fig. 20, work in zones under the direction of a zone superintendent who has charge of as many as 75 units. Another branch of the service is the street-sprinkling department, which uses the equipment illustrated in Fig. 23. These trucks generally operate at night and have tank bodies equipped with high-pressure pumps capable of exerting a pressure of 150 lb. per sq. in. In New York City alone more than 400 of these trucks, each having a capacity of 1500 to 2000 gal. of water, are in use.

Another of the big transportation problems in a city the size of New York is snow removal. Millions of dollars are spent each winter in clearing away the city snowfall, the motorized snowplow shown in Fig. 25 playing a prominent part, and thousands of hired trucks must be utilized to supplement city-owned equipment. In cases of sewers that are clogged, an auto-eductor truck is used which automatically cleans the sewer inlets and catch-basins. It can also be utilized by the park department for spraying trees and shrubs and for snow removal. A considerable amount of equipment, such as road rollers, automatic dump trucks, trucks equipped with concrete-mixing machinery and similar vehicles, is also employed in paving and repairing the streets.

The Fire Department of New York City has more than 1200 different automotive units ranging from express patrol wagons to giant hook and ladder and water-tower trucks, all of this equipment being specially designed to meet certain requirements. A motor-truck that is completely equipped with chemical fire-extinguishers and a pumping engine is shown in Fig. 24. If a fire is raging on the seventh, eighth or tenth floor of a building, an automatic tower shoots a stream of water directly from the truck, without waiting for the fireman to bring the hose up to that floor. At all times of the day and night some part of a city's motor-transport equipment is being utilized. Police patrols, numbering over 200, are in daily service. Emergency rescue squads have high-speed automobile trucks capable of traveling 70 m.p.h.

Rail and Road Coordination

To indicate the attitude of the officials of some of the great railroad systems in the United States on the use of motor transport by railroads, I quote from a speech made at Boston on March 14, 1929, by W. W. Atterbury, president of the Pennsylvania Railroad, who said in part:

> The point I want to make clear is that now is the time to make sure of the future. That is our purpose in coordinating bus and truck service with railroad operations and in the study of numerous projects for improvements and expansion of the railroad plant that are constantly under consideration.
>
> The general policy of the railroads may be summarized by saying that they are now embarking on a comprehensive campaign to combine transport with their own train operations. The Pennsylvania Railroad believes motor service should be conducted in an orderly manner, under responsible management and upon a basis which, in features of safety, reliability, comfort and convenience, will offer patrons service comparable to that of standard passenger-train service. Therefore, in lending its endorsement and support to transportation on the public highways in this manner, and tying such service with its own train operations, it will be the policy of the Pennsylvania Railroad to assure the public that the motor operations with which it is associated will be conducted upon these standards.
>
> With the coordination of railroad and motor-vehicle transportation in our territory, we hope to minimize the wasteful and destructive competition that has grown up over a period of years. That form of competition is never in the interest of the public.
>
> We must be prepared to offer you railroad service where that is more desirable, or bus service, or service by airplane. We must adjust our freight facilities more and more to the needs of the individual shippers. In other words, my view of a railroad is that it should give the people the kind of transportation they want, not what the railroads think they ought to have.

On May 15, speaking before the Bond Club at New York, he further emphasized this policy as follows:

> Rail and road transport coordination may be effected through: (*a*) store-door delivery, English and Canadian systems; (*b*) rail-terminal trucking or trucking supplementary to line-haul service, and (*c*) containers.

The type of container referred to is that shown in Fig. 29.

Store-Door Delivery

Store-door delivery, as practised in various forms in the United States, England and Canada, probably had its origin in the old Pickford van system that was operated in England perhaps a century before the steam railroads came into existence. Pickford & Co. were the principal carriers and transported merchandise by canal boat, stage, wagon, van and cart, between London, Birmingham, Manchester, Liverpool and other large towns. In the early days the vans used the turnpike and carried small parcels and the more valuable freight.

The evolution was that the road-transport companies moved with the tide, so to speak, and formed the connecting link between rail-head and store-door by taking over that movement for the railroads, the result being what we usually term "store-door delivery." In the store-door-delivery service question, four parties are principally interested: the railroad, the merchant, the cartage men and the public. One of the major advantages of a store-door-delivery service is the reduction of congestion at rail terminals. In Canada store-door delivery has been in operation for approximately 70 years. Recent investigations by our Interstate Commerce Com-

mission show that 32 per cent of all railroad damage claims paid in the United States were on less-than-carload freight. In Canada this figure is only 22 per cent, indicating that store-door delivery reduces claims. Store-door delivery, to be a complete success, should provide that the railroads assume full responsibility for the goods from the door of the consignor to the door of the consignee. Such a procedure is followed in Great Britain and secures a truly expedited freight service. In America the railroads have not yet been willing to support a store-door-delivery plan, but to have complete coordination of transportation facilities it is essential that they do so, as it should be an integral part of our transportation structure.

The oldest and best established store-door-delivery service is to be found in England where the railroads have always had it. In the beginning the cartage vehicles were privately owned, but now most of the railroads own and operate the vehicles, performing their own collection and delivery of miscellaneous goods. Delivery of goods begins at the time the car door is opened and ends at the time the cartage vehicle leaves the trader's store door. The major steps between these two are as follows:

(1) Unloading and checking of goods from cars to platform or vans
(2) Barrowing of goods to van-loading sections or warehouses
(3) Loading and checking of goods onto cartage vehicles in district and street order
(4) Removing loaded vehicles from sheds and either the parking of them by van setters or their removal by carmen, accompanied by a pass, over scales and out into town for delivery of goods.

Collection of goods can be divided into four operations as follows:

(1) Traffic carted into station, accompanied by consignment notes
(2) Van loads backed to shed platforms or cars
(3) Unloading of vehicles
(4) Barrowing of goods to car side.

Several good reasons exist why we should study the English system. All but 10 per cent of the miscellaneous-goods traffic in England is delivered to store door the same day it arrives at the terminal, 80 per cent of it before noon. The common practice is to give 24-hr. service on this class of traffic up to 200 miles distant.

Most railroad men fully realize the important place of the motor-truck in the transportation field. A study of the various factors of the problem indicates that, insofar as the proper place of the motor-truck is concerned, a clearly defined field has developed wherein it can successfully supplement steam-railroad service. This includes

(1) Short-haul package freight moved from important distributing centers to points 45 miles distant therefrom and in some instances farther
(2) Short-haul package freight moved from warehouse of the shipper to the receiving platform of the consignee
(3) Distribution by wholesale and jobbing houses to their own customers
(4) Movement of a particular article from the plant of the manufacturer to the distributing centers, in trucks specially fitted to carry the article without the necessity for crating.

Uses actually made of motor-trucks by steam railroads are, in general, as follows:

(1) Transfer of less-than-carload freight between main and sub-stations in the same terminus
(2) Transfer of less-than-carload freight between stations of various railroads in same terminus
(3) Transfer of freight from inland or off-line stations in a terminus to rail stations
(4) Rendering store-door delivery
(5) Rendering store-door delivery through a constructive station
(6) Replacement of package or peddler-car local trains for handling less-than-carload freight between stations on a railroad division
(7) In lieu of lighterage at New York City and other ports
(8) Transfer of freight from shipper's door to railroad cars, involving the use of containers
(9) Transfer of freight between divisions, across country, to eliminate movement through congested terminals
(10) Handling company material between shops and other company buildings and departments.

The prevailing reasons that can be assigned for the adoption of the motor-truck in the operations outlined above, are: (*a*) economy and (*b*) expedited movement. The railroads are operating motor-trucks in several ways:

(1) By the railroads themselves through motor-transport departments
(2) Through subsidiary companies

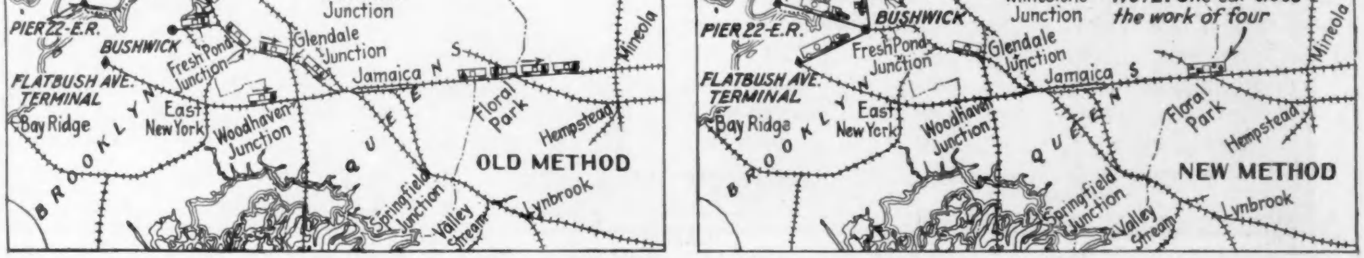


FIG. 26—TRACTOR AND TRAILER COMBINATIONS NOW ENABLE ONE FREIGHT CAR TO DO THE WORK OF FOUR

In the Scheme of Operations Shown in the Map at the Left, Each of Four Terminals in and around New York City Made up Individual Cars for Stations along the Line. Under the New Scheme, Shown at the Right, Freight Is Hauled from Three of These Terminals by Motor-Truck and Trailer to a Centrally Located Station Where a Single Car Is Loaded

(3) Through the medium of contracts with independent companies, which is the plan generally used.

Comparison of Rail and Truck Movement

Data in Table 2 were selected from an average of 30 cities using both truck and freight service and give a composite picture of the general tendency to use the motor-truck for short hauls, where conditions permit. As shown, the motor-truck performs 85 per cent of the short hauls, but its efficiency gradually decreases as the distances increase, which indicates that freight cannot economically be hauled long distances by truck.

Coordination of the motor-truck and the railroad in terminal service is well exemplified by the Long Island Railroad trucking operations handled under contract by the Motor Haulage Co., of Brooklyn, N. Y. This railroad was faced with a serious problem arising from delay and congestion within its four metropolitan terminals, each of which made up a peddler car for each of the various branches; in other words, each station was loading a car for, say, Mineola, N. Y., which meant that four lightly loaded cars were hauled to that point daily, the traffic for which could easily have been loaded into one car. In addition this also meant that four peddler cars were being handled at the Holban Yards Transfer where the facilities were already overtaxed. Delay and congestion were the result of the operations, and something had to be done to relieve the situation. The remedy was the consolidation of freight at specific stations so that more through cars would be made and peddler cars on each train reduced to the minimum number. The motor-truck offered a means to eliminate this delay and the yard congestion by using the highway to connect the various terminals. The actual operation in this particular instance has resulted in having one car carry the tonnage of four. To do this, highway trailers are stationed at each of three stations and transport the freight originating there to a centrally located terminal. The two systems of operation are compared in Fig. 26.

In one month, with one tractor and six trailers in operation, 1629 tons of freight was handled between the Long Island City, Pier 22 and Flatbush Avenue stations and the Bushwick terminal. About 300 freight cars would have been used for this service. According to the railroad's own figures, the cost to move these 300 cars to their destinations, through the yards, including a 4 days' per diem charge, would have been $6,747. Against this amount is charged the hire of motor equipment, the cost of the second handling at the terminal and supervision, making a total charge of $3,855, leaving a net saving of $2,860 per month. The indirect savings, although they cannot well be translated into money value, should be taken into consideration. To be definite, they are:

(1) Savings in floating cars across the East River
(2) Reduction in the number of cars that have to be handled from the terminal stations to Holban Yard, resulting in a saving of per diem charges and cost of movement
(3) Saving in yard operations, such as engine time, labor and similar items, at Holban Yard
(4) Reduction of delays to trains en route by reason of fewer cars to be opened at each station
(5) Increase in capacity of the railroad to handle passenger business, due to the reduced amount of time of line occupancy by unremunerative or slightly remunerative freight service. This is especially important to the Long Island Railroad with its heavy passenger-train operations
(6) Reduction of the detention of freight moving within or through the terminal area from one to four days
(7) More room for additional cars at transfer platforms
(8) Reduction of the number of cars in their daily set-up, resulting in heavier loading of destination cars and fewer peddler or way cars.

One of the best examples of supplementary off-line freight service as developed by a railroad system is found on the Pennsylvania Railroad. It operates a motor-truck service in a territory served by 2860 miles of railroad and having 845 stations that are served daily by a large truck fleet maintained with the minimum of equipment, men and spare parts.

In October, 1923, the Pennsylvania began developing what was probably the first motorized railroad line-haul less-than-carload route. This extended from Philadelphia to Downington, Pa., a distance of 32 miles, and served 27 stations. This operation rapidly increased until at present 16 routes in the eastern region embracing the States of Pennsylvania, Delaware, Maryland and New Jersey are in use. The daily operation in this particular district covers 1500 railroad miles, serving 453 stations. In the western region, which includes Pennsylvania and Ohio, with Pittsburgh as headquarters, operations over 19 routes cover daily 1200 railroad miles and serve 392 stations. Wherever possible, routes are laid out to parallel the Pennsylvania Railroad tracks. In addition, the Pennsylvania has recently established similar trucking services in the territories served from Baltimore, Norfolk and Buffalo, and also in general other terminal-areas in which supplementary line-haul operations will shortly be included.

Container Operations

The container or demountable body is applicable to a number of freight-handling operations. So far their use has been confined to a rather restricted service. In considering their wider application from a railroad viewpoint, we are primarily interested in

(1) The rail haul of freight between terminals where the containers are always on the property of the railroad company
(2) The terminal movement of freight between freight houses and warehouses or store door.

TABLE 2—COMPARISON OF LENGTH OF HAUL BY MOTOR-TRUCK AND RAILROAD

Length of Haul, Miles	Motor-Truck		Railroad					
			Carload		Less than Carload		Total	
	Tons	Per Cent	Tons	Per Cent	Tons	Per Cent	Tons	Per Cent
Under 20	6,091	84.5	1,112	15.4	10	0.1	7,213	100.0
20-39	5,973	54.7	4,803	44.0	145	1.3	10,921	100.0
40-59	2,299	32.0	4,484	62.4	404	5.6	7,187	100.0
60-99	980	24.2	2,409	59.4	663	16.4	4,052	100.0
100 and Over	157	2.3	5,280	77.4	1,383	20.3	6,820	100.0

In the first application, considerable progress has already been made. The Pennsylvania, New York Central, Boston & Maine, and Lehigh Valley Railroads and a few electric railways have inaugurated a container service over portions of their lines. In the second classification, the terminal haul, the use of containers and demountable bodies has been, to a large extent, in the interchange of merchandise between store door, warehouse and factory. These operations have generally been conducted by private individuals or merchants. The object was to reduce the standing time of motor-trucks by having the loading and unloading of the bodies performed while the truck was traveling on delivery work.

The two major systems for handling containers or demountable bodies are

(1) The lift-off or crane system whereby the bodies or containers are removed by cranes and hand hoists

(2) The roll-off body or container mounted on casters or wheels and rolled, either manually or by mechanical means, on or off the truck chassis, freight cars and platforms.

The railroads have made real progress in the first system of container operation, and in the movement of bulk commodities, such as brick, a very substantial saving has been effected in the cost of handling and a higher load-efficiency reached for both car and truck.

The following brief description of container-service operations that have been established by three of our railroads will show what is being accomplished in this field of transportation:

Pennsylvania Railroad.—In the summer of 1928 the Pennsylvania Railroad established a few routes over which a new form of service for less-than-carload freight—the container-car service—was operated. This is based upon the use of portable steel containers adaptable to either specially equipped railroad flat-cars or motor-trucks and trailers, as shown in Fig. 29. The interchangeable feature of the equipment makes possible an effective coordination of rail and motor-truck services.

Five important advantages gained are

(1) Movement of package freight is accelerated in that less handling is necessary

(2) Rail rates are lower than those applying to less-than-carload shipments handled in the ordinary way because the railroad is relieved of loading and unloading, and heavier car-loadings are possible

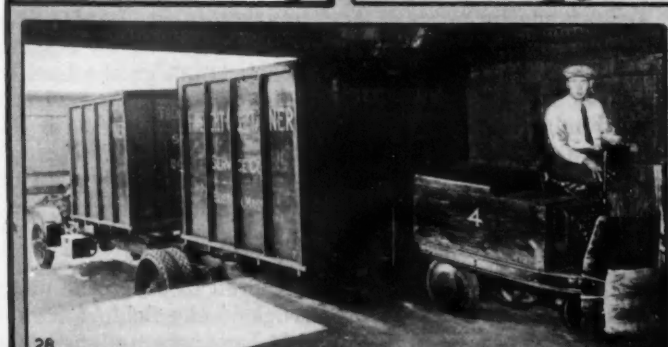
(3) The need for crating or boxing freight is eliminated in many instances, thus reducing shipper's expense

(4) A complete through transportation-service from the door of the shipper to the door of the consignee is offered

(5) Additional safeguards against loss and damage result from the better packing and stowing of goods in the container than is usually possible in a box car, from the decreased number of times an individual article is handled and from the fact that the containers cannot be opened in transit without the use of cranes or other special equipment.

Containers are of steel construction of the following outside dimensions: width, 7 ft.; length, 9 ft.; and height 8 ft. They have a capacity of 440 cu. ft. and an average weight of 3000 lb., with a pay-load capacity of 10,000 lb. The capacity of the flat car is five containers, which, when fully loaded, gives a pay-load of 25 tons of freight. Container-car service is now in force on the Pennsylvania Railroad between the following points: New York City, Philadelphia, Baltimore, Pittsburgh, South Kearney, N. J., Cleveland and Buffalo. This service will be further expanded as the public becomes familiar with the advantages of the container and traffic demand warrants. In connection with the use of containers, shippers have a choice of the following types of service:

(1) For originating store-door to



THREE EXAMPLES OF CONTAINER OPERATION

Fig. 27—In the System Used by the New York Central Lines, Six of the Containers for Less-than-Carload Freight Are Transported on a Specially Constructed Flat-Car. Fig. 28—Industrial Tractor Unloading Freightainer Containers from a Motor-Truck for Transportation on Flat-Cars over the Lines of the Boston & Maine Railroad. Fig. 29—Containers Used by the Pennsylvania Railroad Loaded on Motor-Truck and Trailer for Delivery to the Consignee from the Railroad Freight Terminal

destination store-door, relieving both shipper and consignee of trucking

(2) From originating station to store-door destination, thus permitting consignor to truck containers or freight

(3) From originating store-door to destination station, thus permitting consignee to truck containers or freight

(4) From station at point of origin to station at point of destination, thus permitting both consignor and consignee to truck containers or freight.

New York Central Railroad.—The merchandise container has a capacity of 438 cu. ft., with outside dimensions of 7 ft. 2½ in. of length; height, 8 ft. 2½ in.; and length over guides, 9 ft. 2½ in. Inside dimensions are: width, 7 ft.; height at eaves, 7 ft. 1 in.; and length, 8 ft. 10 in. Each container is provided with eyes at the four corners which are an extension of the lifting straps by which an overhead crane can lift it from truck to car or reverse the movement. The container is fitted into place on the railroad car by guides or slots that hold it firmly in place, thus avoiding the possibility of side-sway or movement of any kind. Each container can handle a maximum load of 8500 lb. of miscellaneous freight which, under the present rate-structure, makes it advantageous for the skipper to load the container to as near capacity as possible. With each fully loaded, a car of six containers (Fig. 27) accommodates 51,000 lb. of mixed merchandise, as compared with the ordinary loading of merchandise in box cars of 15,000 lb. per car.

The containers are loaded by the shipper and unloaded by the consignee, which, when compared with ordinary less-than-carload freight handling, means a considerable saving to the railroad in labor alone. All articles on the list approved for container service are charged at the same rate, which is a certain figure per mile for a minimum-tonnage loading per container.

The containers for handling bulk freight, such as brick, refuse, quarry stone and other bulk materials, present a somewhat different situation from that of the merchandise container. The brick or bulk-freight containers have dimensions approximately one-half those of the merchandise containers. The inside dimensions are: width, 4 ft. 1 in.; height, 7 ft. 4¾ in.; and length, 6 ft. 11¾ in. Outside dimensions are: width over guides, 4 ft. 8¾ in.; approximate height over lifting brackets, 8 ft. 4 in.; and length, 7 ft. 2½ in. Their capacity is 210 cu. ft. and the average light weight is 2300 lb.

In practice, the river-barge or flatboat water-transportation service involves the manual handling of the brick from kiln into a wheelbarrow, pushing the wheelbarrow across the dock, over a plank onto the barge where the brick must be stacked and, at the destination, the brick must be tossed from barge to a man standing on the stringpiece of the dock, who in turn throws the brick into the truck. Shipping the brick by rail box-cars is also a very slow and costly performance. With the container method, in the most modern plants the brick is loaded automatically by machinery and the containers holding 3000 brick are lifted by crane at rail terminals, brought into position over the truck body and dropped to within 1 ft. of the truck, then the bottom is slowly opened by this same crane without actually setting the container down, which permits the brick to slide, not fall, into the truck body. A container is unloaded in 4 min. by this method.

The motor-truck, of course, plays a very important part in the use of the bulk container. The New York Central Railroad has not attempted, however, to do more than use the trucking agencies available on the basis of a contract with independent truckmen rather than to operate trucks direct.

Boston & Maine Railroad.—The Freightainer service, as worked out on the Boston & Maine Railroad and illustrated in Fig. 28, is a good example of the roll-off container system. The operation is carried on by the Freight Container Service Co., of Boston, and is operated over the rails of the Boston & Maine Railroad, serving Boston, Worcester, Springfield and other points. Empty steel containers capable of carrying up to 5 tons each are brought to the shipper's door by motor-truck. At destination the loaded Freightainers are taken from the car by motor-truck directly to the door of the consignee, where they can be unloaded without being removed from the truck or rolled to any part of the consignee's building for unloading.

A good example of the saving made in the cost of loading has been found in transporting shoes. A single Freightainer load of shoes, where the shoes are loaded at the end of the production line in the factory and unloaded at the retail store, may save as much as $50 in wooden packing boxes and from 4 to 14 handlings of the shoes. Also, pilferage and other loss and damage claims are greatly reduced and the shipment expedited.

The Motor-Truck and Air Transport

The coordination of railroad and motor-transport facilities has no sooner been partly solved than we find a still more modern transportation facility ready to be fitted into the general transportation structure. Mail, express and baggage must be carried between airport and post office, railroad and express terminals in an expeditious way if we are to obtain all the advantages of the swiftest transport facility available; that is, the airplane. High-speed pneumatic-tired motor-trucks are the vehicles that meet these requirements satisfactorily, and though this field is as yet small, potentially it holds out excellent opportunities for a high-class trucking business and one that will grow rapidly once air transportation gets into full swing.

A good illustration of intensive use of rail, road and air transport facilities is in the southwestern part of the United States in the handling of fresh shrimp. Much of this seafood is caught near the islands off the coast of Texas and the nearest large market is St. Louis. Seaplanes collect the shrimp at these islands, fly several hundred miles to Houston Airport, transfer the load to fast motor-trucks that deliver the shrimp to the railroad terminal, from which express trains rush them to St. Louis and so, again, by truck to market place and hotel. This makes it possible to eat shrimp only 36 hr. out of the water, 1000 miles from where they were caught.

Conclusion

In the foregoing I have endeavored to cover the most important uses of the motor-truck in the field of transportation. That much has already been accomplished and great progress made is very apparent, and yet we can safely say that the movement of freight by motor transport is still in its infancy. Our largest problem remains one of application of this new transportation tool to present requirements. Intensive and comprehensive use

(*Concluded on p. 629*)

A Study of Engine Oil-Filters

By A. H. Hoffman[1]

Northern California Section Paper — *Illustrated with* Photographs and Charts

THE PAPER is a preliminary report on a study of engine oil-filters made at the University of California Agricultural Experiment Station in connection with research on the effect of character and condition of lubricant on bearing wear. It is similar in its general character to the papers, presented at the 1924 Semi-Annual and the 1925 Annual Meetings, giving data on air-cleaner tests made under the direction of the author.

To determine what the engine-crankcase oil-filter removes, a number of used filters were obtained, principally from vehicles used by the California Highway Commission, the dirt and filter material removed and incinerated, and the ashes weighed and chemically analyzed. The results of this work are tabulated and the quantity of ash remaining after incineration serves as a measure of the solid foreign matter removed from the oil. Practically all of this was abrasive material, consisting of silica, iron, lead and copper in determinable quantities, with traces of tin, manganese, zinc, chromium, magnesium and antimony.

To find a means for evaluating the service of an oil-filter in reducing engine wear, a test was made on two automobiles after each had been given about 10,000 miles of approximately equivalent use, during which one engine had the oil-filter bypassed. The average wear on the piston-rings was approximately twice as much on the machine without the filter.

How the oil-filter affects draining the crankcase was studied on a trip of 10,025 miles in midsummer across the United States and back to the Pacific Coast. Viscosity tests gave practically identical curves for the two trips and showed that the low point was reached before a new charge of oil had been in use for 200 miles and did not change appreciably thereafter. The acidity rose rapidly in the first 200 or 300 miles after draining and remained almost constant thereafter.

AS PART of a project on bearing wear as affected by the character and condition of the lubricant, the agricultural engineering division of the California Agricultural Experiment Station is undertaking a study of engine oil-filters, which ultimately may be rather inclusive. The first work here reported has mainly to do with the results of (*a*) chemical analyses made of the contents of 25 used filters, (*b*) a test of comparative wear in two automobile engines of the same kind after similar periods of service during which one engine had the oil-filter bypassed, and (*c*) a test run made to study the behavior of oil in crankcases not drained for long periods.

To determine what service crankcase-oil filters render, a number of used filters were obtained on which service data were available. These were cut open with care to avoid contamination with bits of metal from the containers, the dirt and filter material removed and incinerated, and the ashes weighed and chemically analyzed. The results are given in Table 1 and include a partial analysis by H. W. Allinger giving the various substances found expressed as percentages of net ash. In addition to the silica, iron, lead and copper reported, traces of tin, manganese, zinc, chromium, magnesium and antimony were found in all filters.

Sources and Types of Filter Tested

Filters Nos. 1 to 14, 17, 18, 23 and 24 are from automobiles in the regular service of the California Highway Commission. The other filters are from privately owned passenger-cars. All the filters except Nos. 21 and 22 were used principally in California and probably are typical except as will be pointed out later. Except where otherwise indicated in the table, the filters are assumed to be the original ones that were installed at the factory.

All the filters tested are of one type, that in which the filtering element is of cotton flannel or similar material. In some cases part of the solids could be drained by removing a plug in the bottom of the filter case, but no indication was given in any of the 25 filters listed that such draining had occurred, and we assumed for the purposes of this report that none had occurred. Several elements from used Hall-Winslow filters were available, but in every case analysis seemed useless because evidently the bulk of the filtered-out solids had been drained out and lost.

No attempt was made to determine the carbon in the filters, as separating all of it from the filter elements seemed impossible. The carbon content varied widely, probably due largely to differences in mileages and, to a smaller extent, in characteristics of the several machines, the care given and service required, and the kind of oil used. Most of the filters that had been used for 10,000 miles or more were rather well filled with carbon and dirt. The interior of filter No. 11, which had run 25 months and 53,000 miles, was a solid block of caked carbon. Fig. 1 shows one of the filter elements from this cleaner. As will be noted from Table 1, the ash from this filter was considerably less, both by total net weight and the weight per 1000 miles, than that from many of the others that had been used fewer miles. Undoubtedly the bypass valve had been open for most of the 25 months because of the restriction due to the carbon in the filter. That carbon rather than other solid matter limits the useful life of cloth-type and similar filters seems to be borne out by the record of filter No. 23, discussed later, which had only about 3500 miles of service but under extremely dusty conditions.

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Condition of Interior of Filters

The condition of each filter opened was observed. Two, Nos. 9 and 13, had some of the filter elements ruptured. This undoubtedly was due to two causes: the weakening of the filter material and the warped condition of some of the metal expanders inside of the filter elements, as shown in Fig. 2. Because of the warped condition, these expanders exerted excessive forces on the cloth. The weakened or brittle condition of the cloth may have resulted from overheating of the oil as a result of an empty radiator or from acidity caused by the use of gasoline having a high sulphur-content. Only about 4 per cent of more than 100 filters opened thus far have shown failures of this kind. The suggestion that some such failures may be caused by the freezing of water within the filters is regarded as improbable because in every case of rupture the filter was of the type that retains the solids on the outer surface of the cloth. Hence the water, if any, would not be within the individual filter-elements.

In explanation of Table 1, we should like to point out that the quantity of ash remaining after the filter cloth and the dirt it collected have been incinerated gives a good idea of the quantity of solid foreign matter other than carbon that has been removed from the oil. This is practically all abrasive material, though, of course, the silica present would be more highly abrasive than the iron and other metals. The silica comes principally from the road dust drawn in through carbureter and breather, poured in with oil handled in dusty funnels and vessels, and from the silica content of the abraded cast iron. The iron is chiefly that worn off cylinder-walls and piston-rings, though an appreciable quantity undoubtedly comes from road dust. In the dust encountered by the automobile on which filter No. 23 was used, we found considerable iron. The lead and copper probably came principally from babbitt and bronze bearings and from lead deposited from doped gasolines. Lead is somewhat volatile at temperatures that may have been reached in the process of incineration, hence some of the values for the percentage of lead may be too low. The other metals, traces of which were found in the filters, came from the alloy steels used and from bearings.

TABLE 1—WHAT THE CRANKCASE-OIL FILTER REMOVES

Test No.	Car	Filter Applied	Filter Removed	Time Used, Months	Mileage	Filter	Net Weight of Ash, Gm.	Net Ash per 1000 Miles, Gm.	Ash Insoluble in Hydrochloric Acid or Aqua Regia[2]	Silica in Insoluble Ash[2]	Soluble Silica[2]	Iron as Ferric Oxide[2]	Lead as Lead Oxide[2]	Copper as Cupric Oxide[2]
1	1927 Cadillac 314	10/ 8/26	12/10/27	14	16,352	Purol A3	41.70	2.55	10.07	8.00	1.03	54.67	1.78	6.12
2	1926 Buick Standard Six	6/ 4/26	8/ 1/27	14	28,094	Purol A2	46.75	1.66	8.79	7.00	0.25	61.85	1.30	2.65
3	1927 Buick Standard Six	6/ 3/26	10/ 7/27	16	31,199	Purol A2	51.04	1.64	5.25	4.30	0.36	76.12	1.17	3.89
4	1925 Studebaker Special Six	4/ 7/26	8/ 1/27	16	25,814	Purol A2	50.67	1.96	6.31	5.10	0.34	67.61	4.13	2.61
5	1926 Buick Master Six	4/28/26	10/30/26	15	32,998	Purol A2	59.38	1.80	12.60	10.00	0.52	54.35	2.93	4.63
6	1926 Studebaker Big Six	11/30/26	12/28/27	13	27,288	Purol A2	40.00	1.47	19.50	14.20	0.09	65.79	0.04	0.80
7	1926 Oakland	[a]	8/ 9/27	[a]	26,322	Purol A1	44.67	1.70	10.76	7.90	0.13	69.07	2.28	1.57
8	1925 Chrysler 70	12/29/25	8/ 1/27	19	33,220	Purol A1	51.26	1.54	9.80	7.50	0.30	56.74	11.55	1.27
9	1926 Chrysler 70	10/ 5/26	2/6/28[b]	16	24,310	Purol A1	23.52	0.97	5.32	4.40	1.28	68.42	3.30	2.29
10	1926 Peerless 680	4/29/26	5/21/27	13	18,728	Purol A1	60.59	3.24	11.80	8.50	0.25	59.73	9.31	1.71
11	1925 Chrysler 50	6/12/25	7/26/27[c]	25	53,035	Purol A1	13.55	0.26	18.46	13.90	0.31	55.88	1.37	1.75
12	1926 Chrysler 60	11/13/26	8/ 1/27	9	26,947	Purol S2	38.15	1.42	10.20	7.60	0.31	53.22	13.66	1.88
13	1926 Chrysler 70	1/22/27	2/15/28[d]	12	24,205	Purol S2	9.92	0.41	6.46	5.40	0.25	68.73	2.84	1.58
14	1927 Studebaker Commander	6/ 9/27	2/ 6/28	8	18,732	Purol S3	12.64	0.67	10.79	7.80	0.32	65.87	4.48	4.76
15	1928 Buick 28-26S	10/15/27	4/23/28	6	5,000[e]	A. C.	14.42	2.88	6.34	4.90	0.77	60.71	3.30	7.36
16	1928 Buick 28-20	10/27/27	4/18/28	6	1,851[f]	A. C.	14.51	7.84	4.80	3.70	0.55	67.21	2.71	1.90
17	1928 Chevrolet National 6AB	[a]	5/25/28	[a]	78	A. C.	2.15	27.60	7.68	6.40	0.32	76.29	5.09	2.20
18	1927 Cadillac 314	[a]	[a]	[g]	5,187[h]	Purol A3	27.60	5.32	38.10	18.40	2.47	47.84	4.41	5.73
19	Buick Standard	[a]	[a]	[a]	10,000[i]	A. C.	50.24	5.02	12.79	10.30	0.86	68.44	2.35	4.02
20	Dodge Senior Six	[a]	[a]	[a]	32,000	A. C.	62.72	1.96	9.24	6.20	0.22	61.26	23.52	1.68
21	1926 Buick 26-20	[a]	6/28	[a]	6,800[j]	Purol A3	78.48	11.50	3.20	2.40	0.48	80.25	11.19	3.06
22	1928 Buick 28-20	4/19/28	7/26/28	3	10,877[k]	A. C.	15.40	1.41	9.84	7.80	0.33	52.89	19.82	3.00
23	1928 Dodge Victory 6	6/28	9/28	3	3,478	A. C.	267.47	76.90	32.19	27.40	2.10	51.59	0.02	1.41
24	1928 Chevrolet National 6AB	5/ 1/28	12/ 8/28	7	11,331[l]	A. C.	28.60	2.52	17.85	13.10	0.42	59.52	1.88	1.27
25	1926 Nash Light Six, Sedan	10/ 2/26	1/10/28	15	10,158[m]	A.C.A1	47.68	4.69	7.43	5.60	0.09	64.70	7.76	2.39

[2] Expressed as percentage of net ash.
[a] No record.
[b] Two elements found ruptured.
[c] Filter was filled solid with carbon.
[d] Some elements found ruptured.
[e] This car was driven principally in the Sacramento Valley.
[f] Oil changed twice.
[g] Third filter on car in 62,000 miles.
[h] Connecting-rod bearing burned out.
[i] This car was driven principally in Southern California.
[j] This car was used in and around the City of Washington.
[k] Two filters used with this car, the first having been removed after 1851 miles. This car was driven across the United States twice.
[l] Mileage divided approximately equally between Sacramento Valley and mountain roads.
[m] This car was driven in the Sacramento Valley and made one trip to Yakima, Wash.

Normal Ash for 10,000 Miles

The record of filters shown in the table seems to indicate that normally a filter may remove from 15

to 50 gm. of solid matter, other than carbon, in 10,000 miles of ordinary running. The weight would depend upon the efficiency of the filter, the size and construction of the machine, the air-cleaner equipment, the placing of the air inlet of the carbureter, the climatic and weather conditions, the humidity and soil types of the region in which the machine is used, the suitability of the oil used and the habits of the car operator. As would be expected, the quantities of solids removed in the first few hundred miles of use of a new machine are relatively larger than later, as exemplified in filters Nos. 16, 17 and 22. Filter No. 22 is the second filter used on the same machine as that of filter No. 16. Another item of importance is whether the service requires many stops and starts with a cold engine or is mostly of long trips. Probably the high total-ash and high iron-content but low silica-content of filter No. 21 was due to this cause, city use in winter; though it may have been due to a careless use of the choke or a carbureter adjustment for too rich a mixture, causing the lubricant to be washed off the cylinder-walls.

Filter No. 23 is a good example of the service rendered by the filter when a car is operated under conditions of extreme dustiness and indicates the large capacity a filter has for removing dust and products of wear so long as too much carbon has not accumulated. The machine on which it was fitted was in the service of the California Highway Commission and was operated between Oroville and a road-construction camp about 16 miles out. The dust conditions were so extreme that after approximately each 100 miles the carbureter and connecting tubes had to be taken apart and the collected dirt removed. One such lot of dust weighed dry 99.48 gm., or about 1 gm. per mile, the normal value for an average car on California roads being 0.001 gm. This 1 gm. per mile was not the total entering the air-cleaner, since presumably the cleaner removed some and very evidently plenty went on into the engine, as the machine, after three months and 3478 miles of use, required regrinding of the cylinders and 0.015-in. oversize pistons.

Filters that had the clean-oil outlet at the top of the filter container or housing invariably had considerable water in the sump. In the case of filters that caught the solid matter on the inner surfaces of the filter elements, the water was usually found distributed in the filter material. Sputtering and some loss of solid material resulted when the damp filters were incinerated. The use of an electric vacuum-oven obviated this difficulty. A vacuum of 26 in. of mercury and temperature regulation from that of the room to about 300 deg. fahr. were obtained and gave good results.

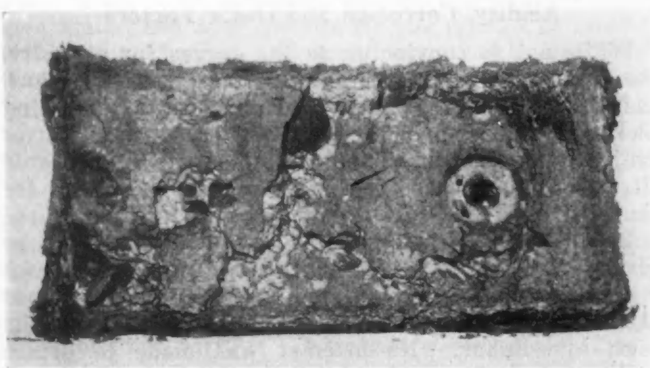

FIG. 1—ONE OF THE FILTER ELEMENTS

This Particular Element Was from a Filter That Had Been Used for 25 Months and 53,000 Miles. The Interior Was a Solid Block of Caked Carbon, but the Total Net Weight of Ash and the Weight per 1000 Miles Were Much Less than Those from Many Other Filters That Had Been Used Less Severely

Comparisons of mileages and net weights of ash for the different filters given in Table 1 can give no very dependable conclusions in the absence of additional data, for the reason that we could not tell which, if any, besides Nos. 9, 11 and 13, were bypassing at any time. Probably several of the others were only partly operative for considerable periods. Some 40 additional filters that were almost all removed at about 10,000 miles have been incinerated and are awaiting analysis.

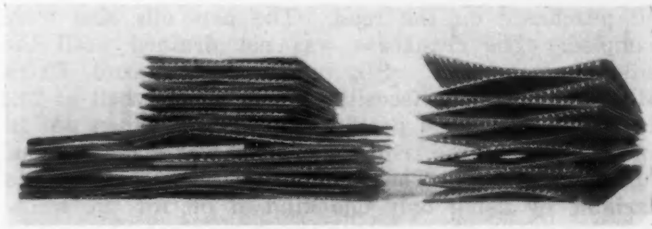

FIG. 2—RUPTURED FILTER-ELEMENTS WERE FOUND IN SEVERAL INSTANCES

The Cause of Failure Was Evidently the Weakening of the Cloth Due to Acidity or Heating and the Warped Expanders Putting Too Much Stress on the Cloth

The majority of these are the original installations but a number are replacements. The trend of these should give further light on allowable mileage.

Reduction of Engine Wear

To find a means for evaluating the service of an oil-filter as reducing engine wear, a comparative test was made of two machines in the service of the California Highway Commission. Both were Chevrolet Nationals Model 6 AB. After measuring and, where feasible, weighing the principal wearing parts of the engines, the oil-filter on one, a roadster with delivery body, was bypassed, while on the other, a coach, it was left as received, and both machines sent out into regular service. After each had been given about 10,000 miles of approximately equivalent use, the machines were sent in and remeasured. The average wear on the piston-rings as determined by loss of weight was approximately twice as much on the machine without the filter. The wear on pistons, cylinders, wristpins, crankpins and crankpin bearings was too slight to justify the drawing of any conclusions. After the first test, the oil-filter conditions were interchanged and the two machines sent back for another 10,000 miles of service to eliminate inherent differences in the machines themselves. Five other cars of one make variously equipped as to oil-filters and air-cleaners have been measured similarly and sent out into service, but none has yet completed the first 10,000 miles.

How Oil-Filter Affects Crankcase Draining

If the filter removes the solid foreign matter from the oil in the crankcase, draining as frequently as has been commonly recommended would seem unnecessary, unless dilution, corrosion and sludge troubles should become excessive. To secure information as to changes taking place in the character of the lubricant in crank-

cases not drained for long periods, oil samples were taken during two trips across the continent made in June and July, 1928, and tested for viscosity and acidity. Consideration should be given to the fact that the trial was made in midsummer and involved but one machine.

A Buick 28-20 Standard Coach was run in this test from Davis, Calif., to the City of Washington and New York City and return, a total distance of 10,025 miles, including side trips. Before the start of the trip the crankcase was drained and 6 qt. of Pennzoil Extra Medium, having a viscosity of 58 sec. Saybolt at 212 deg. fahr. and 0.003 per cent acidity was put in. Two-ounce oil samples were drawn from the test cock on the oil-filter just before adding each lot of new oil purchased on the road. The new oils also were sampled. The crankcase was not drained until the mileage was 5098. Six quarts of Pennzoil Extra Medium, having a viscosity of 55.5 sec. Saybolt at 212 deg. fahr. and 0.004 per cent acidity, was then put in and the rest of the trip, 4927 miles, was made without further draining. The intention was to eliminate one variable by using only one kind of oil for the whole trip, but when the original brand was not obtainable, Mobiloil A was called for. Judging by their viscosities and acidities, nearly all the oils bought were as represented; however, we found some substitutions, one of which, 2 qt. bought at 800 miles on the June trip, was apparently one of the prediluted brands. The results for the two parts of the trip are given in Figs. 3 and 4.

The viscosities were taken by a ball-and-tube type viscosimeter calibrated by comparison with a standard

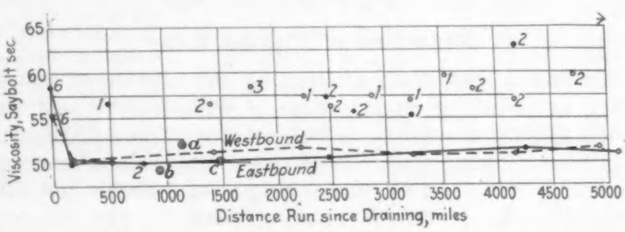

FIG. 3—VISCOSITY CURVES OF THE CRANKCASE OIL USED ON A TRANSCONTINENTAL TRIP

These Curves Are for a 10,025-Mile Trip from Davis, Calif., to the City of Washington, New York City and Return with a 1928 Buick Standard Coach, equipped with an A. C. Oil-Filter and a Bowden Air-Cleaner. The Oil Mileages Were 425 Miles per Qt. for the Eastbound Trip and 235 Miles for the Return Trip, the Lower Figure for the Latter Being Caused by Leakage Past the Gaskets. The Gasoline Figures Were 16.3 and 17.5 Miles per Gal. Respectively. The Numerals Show the Quarts of Oil Added and the Position of the Dot on the Chart Shows the Viscosity of the Lubricant and the Mileage Run Since the Crankcase Was Drained. The Solid Dot Indicates that the Oil Was Added on the Eastbound Trip and the Open Dot, on the Return. Points *a*, *b* and *c* Represent the Viscosity of Three Samples Taken Subsequent to the Completion of the Trip on Oct. 11, Nov. 17 and Dec. 28, 1928, Respectively

Saybolt. The viscosity given for each oil sample is the average of not less than six tests. The acidity determinations, at least in duplicate, were made by the total-acid method[3]. As will be noted in Fig. 3, the viscosity curves are almost identical for the two trips. In both cases the low level is reached before the new 6-qt. charge of oil has been in use 200 miles and does not change appreciably thereafter. The fact that in general crankcase oil very quickly reaches a rather definite level of viscosity was established several years ago by tests made on the proving grounds of some of the automobile manufacturers. The points *a*, *b* and *c* on Fig. 3 show the viscosities of samples taken from the same machine subsequent to the long trips. In each case the date of sampling is given and the viscosity and miles run since the last draining are shown by the position on the graph. The *a* sample was in use from July 26 to Oct. 11, the *b* sample, from Oct. 11 to Nov. 17, and the *c* sample from the latter date to Dec. 28. Aside from two trips of 84 miles each on Oct. 12, no

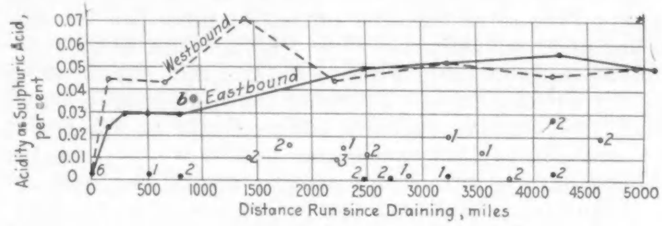

FIG. 4—ACIDITY CURVES FOR THE CRANKCASE OIL USED ON 10,025-MILE TRIP

As in Fig. 3, the Numerals Show the Quarts of Oil Added and the Position and Character of the Dots Indicate the Acidity of the Lubricant and When It Was Added. Sample *b* Was Taken on Nov. 17, 1928

trips of more than 40 miles were made and the bulk of the mileages was made up of trips of less than 15 miles. Notwithstanding the short trips and the cooler weather, the viscosities still fall close to the level for the long trips. Only the *b* sample was tested for acidity, with the result as shown on Fig. 4.

On Jan. 10, 1929, the cylinder-head was removed from the engine on which these tests were made and the valves and cylinder-walls inspected. No evidence of scoring or undue wear was found and the valves were all in good condition. Further evidence that the engine did not suffer because of the infrequency of crankcase draining is furnished by the chemical analysis of the solids in the oil-filter, No. 22 in Table 1, that was on the machine during the 10,000-mile trip. The total ash per 1000 miles is appreciably less than the average for other presumably normal machines on which analyses of filter contents were made. However, the use of an air-cleaner of high efficiency was in a considerable measure responsible, jointly with the oil-filter, in keeping wear at the minimum.

Acidity, Corrosion and Other Factors

While not so convincing as the curves for viscosity, the curves for acidity reproduced in Fig. 4 show much the same character; namely, a rapid rise to something like a normal level in the first 200 or 300 miles after draining and not much change thereafter. Repeated titrations show that the high peak on the curve for the return trip in July is not due to a mistake in the determination. Two possible explanations may be given: the new bottle into which the sample was drawn may have been contaminated, or the gasoline used shortly before the sampling may have been abnormally high in sulphur. No attempt was made to obtain highly refined gasoline. Usually the cheapest was purchased. On one or two occasions doped gasolines were purchased when no other was available. Even the highest percentages of acid found are very small and probably would do no harm in the engine. Corrosion tests using strips of bright copper showed practically

[3] See Technical Methods of Analysis, by Robert C. Griffin, p. 335.

no effect at all even when protracted for several weeks.

Other factors entering into this test should be mentioned. A crankcase ventilator is regular equipment on the machine used. Its use would tend to raise viscosity and to lower acidity.

While the oil mileage was 425 miles per qt. going and only 235 returning, this large difference in oil consumption was due principally, if not wholly, to difference in leakage past crankcase gaskets. Crankcase bolts and capscrews were tightened just before the trip. Leakage was noticeable during the return trip. After the return, the bolts were given proper attention and the oil mileage rose again to nearly its original value. Leakage would keep up viscosity and keep down acidity by the partial draining and more frequent addition of new oil. That this effect was inconsiderable seems clear from the curves.

During the first part of the going trip the carbureter was adjusted for somewhat too rich a mixture and during the rest of the trip it was probably still a little richer than necessary. This would tend to greater dilution and lower viscosity. On the other hand, the mixture heater was left on practically continuously, which would have the effect of making combustion more complete and therefore reducing dilution. The engine was just nicely run-in at the start of the trip, hence leakage past the pistons would be slight, tending to minimize dilution and acidity.

Motor Transport of Freight

(*Concluded from p. 624*)

of the truck in the short-haul areas of large cities and in coordination with rail transportation presents opportunities for expansion that are greater than anything yet reached.

We frequently hear the statement that when the railroads once make extensive use of motor transport, when the container method is fully developed and store-door-delivery service is universally established, the independent truck-operator will be put out of business. I say that this is a fallacy. New methods will bring about new and more intensive use of modern machinery, including the motor-truck. Ample work will be found for all forms of transportation, just as has been the case for the old and new forms of communication—the telephone and telegraph, and now the radio. All we need to give us the right perspective on these things is common sense, which can well be defined as a scientific use of the imagination. Modern transportation facilities are vital to the progress, security and comfort of every country, and the motor-vehicle, because of its inherent mobility and relatively low cost, fills a most important place in the all-embracing picture we view.

European Economic Union

ALL of Europe's 400,000,000 people do not at present consume as much as 120,000,000 Americans, yet are very eager to reach America's standard of living. They cannot do so unless they apply the broad-scale economic principles America has demonstrated to be a success. Heretofore national boundary lines and tariffs have cursed Europe with barriers every few hundred miles. It is precisely as if business firms could sell goods in only one State of the United States, and as if customs officials bristled at every one of our State borders. We Americans would be appalled and severely checked in prosperity by such a condition. We could not have mass production if General Motors or Campbell's soups were virtually compelled to do business in Michigan or New Jersey alone. Europe is therefore writhing in a set of economic strait-jackets of her own making, and it would be a narrow American view which would wish that she continue to confine herself in them.

The best American opinion is in favor of the European economic union. Newton D. Baker says:

It seems to me that such an agreement is necessary, for one of the unhappy developments after the war was the building of tariff barriers. These have grown so high that they not only keep out foreign manufacturers but throttle home industry. Every movement of the kind Briand proposes helps to preserve the peace of the world.

Julius Klein, Assistant Secretary of Commerce, says:

Any fundamental contribution to European prosperity and general economic stability, if it be not involved with discriminatory intent, either open or concealed, will react favorably upon the buying power of the Old World and will have repercussions favorable to America.

Robert S. Brookings, founder of the Brookings Economic Institute, believes that the economic union "is in our interest as well as that of Europe." It should also be borne in mind that both Briand and Stresemann disclaimed that the proposed economic union is directed against America.

The late German Premier had the courage to advocate, as one of the plans for an economic union, a single currency system for the continent. This is indeed a step forward, as every American tourist will appreciate!

In all planning and thinking, the thought of the statesmen and business men is to attain for Europe something like the wide, unhampered market and economic field for development such as America enjoys by reason of being one economic unit from Atlantic to Pacific.

Through the increase of real wages and standards of living in Europe, our tariff would in effect be modified due to the increased purchasing power of a day's labor which would arrive in Europe. It is at present a real menace to international understanding to have standards of living show such violent contrasts between America and the rest of the world.

Equally true is the opposite side of this principle. Weakness in trade breeds more weakness throughout the economic world. Those who speak of a European economic union as a shield against "American domination" or as a sword to thrust at America have little standing in responsible councils.—J. C. Frederick, in *Trade Winds*.

Engineering and Service Relationships in the Truck Industry

By E. D. Sirrine[1]

Transportation Meeting Paper

Relationships that should exist between the engineering and service departments of the motor-truck manufacturing company, and between both these departments and the truck owner, are discussed from the unprejudiced and independent viewpoint of a writer who has had experience in both the engineering and service departments but is some years removed from each.

Being far enough out of the woods to see the trees, he presents the responsibilities, obligations and opportunities of the design engineers, service men and even the fleet operator in a light that may be unaccustomed to their restricted vision.

Cooperation, tolerance and a meeting on common ground to discuss mutual problems are urged in the interest of all concerned and of the automotive industry in general.

The engineer can learn much of value from the service man and be of great assistance to him and to the truck owner.

I CANNOT but feel that two considerations entered into my having this opportunity to address your body on the subject of the proper relationship which should exist between the engineering and service departments in the motor-truck industry; first, that the speaker must have had sufficient experience in both branches to warrant his remarks; and, second, that he must not now be connected with a manufacturer in the industry, else the remarks he probably would make might render him *persona non grata* with his employer. To one some years removed from either branch, the situation is not quite what one who is directly connected with either engineering or service branches presumes it to be; he gets a better view of the woods when somewhat removed from the trees.

First, I desire to outline the problem confronting each division, and the present spoken or unspoken attitude of each branch toward the other, so that I can more clearly indicate what I believe the relationship should be.

In the passenger-car field the engineer is paramount in meeting the comparatively simple problem. The work to be performed by the passenger-car is the same throughout the Country; the service is the same, so long as the car is correctly designed to meet all conditions of climate and terrain, and it is necessary only to design to meet the most severe conditions of both. The designer who best meets these conditions and at the same time provides for excellence of appearance and performance, and who is backed by a manufacturing organization capable of producing the design with the highest workmanship at the lowest cost, coupled with a proper merchandising policy and capable sales force, cannot but be eminently successful. Yet the modern passenger-car has been and is the product of evolution rather than of any spectacular engineering feat.

While the work to be performed by the passenger-car is the same in all cases, that is, the movement of a predetermined number of passengers, and varies only in the matter of climate and terrain, the truck manufacturer has the added task of providing for the efficient handling of every kind of merchandise under every condition of loading and unloading, at an operating cost that will make his product attractive to the business man in the face of the older established methods of transportation. This difference in problems readily explains the very slow progress of the truck industry in comparison with the phenomenal growth of the passenger-car business. Too many engineers in the truck industry assume their problem to be the same as that of the passenger-car engineer; and many engineers in the truck field were formerly in the passenger-car field.

The passenger-car field lends itself beautifully to mass production by the very simplicity of its problem. And it has been the constant endeavor of the truck manufacturer to place his business on a high-production basis so as to secure the consequent low manufacturing costs and lower selling price demanded by both the buyer and his own sales force. As a consequence, too little attention has been given to the diversified haulage problems of the different industries.

The truck manufacturer, in his desire for mass production and its attendant advantages, has endeavored to manufacture standard models of the various capacities in the belief that the haulage problems in different commodities are the same. It has been impossible to convince the truck manufacturer that each industry has its own haulage problems which must be met in a way sometimes quite different from that of another industry handling different materials. No proper relationship between the engineer and the service department can be had without consideration of the owner and his transportation problems.

Haulage Requirements Complicate Service Problem

In the purchase of automotive equipment, what does the owner want? What are his definite needs as relating to the function of the engineer and the service man? Permit me to capitalize one remark: The owner

[1] Automotive Department, Borden's Farm Products Co., Inc., New York City.

knows his business and its ramifications better than the manufacturer of motor equipment will ever know them, but in most instances he knows nothing of the technique of motor transportation, his own opinion to the contrary notwithstanding.

It was necessary for the passenger-car engineer to design what he believed the public required; public demand followed engineering design, in a measure. This same trend of thought has been altogether too prevalent in truck engineering. The buyer will stand for many things in passenger-car design that he will not countenance in the cold business of motor-truck haulage, for practical and economic reasons.

The service personnel of the truck manufacturer has had the problem of adapting various standard models to different industries. The model eminently suited to haul a specified tonnage of one commodity in one industry presents many difficulties when hauling the same tonnage of another commodity. Unquestionably, this service personnel has not the training to meet these problems as would a properly interested engineering personnel, but they have been and are the task of the service man. He must meet them as best he can, making many errors, and generally is successful or fails in direct ratio to his experience. The service man cannot understand the aloof manner of his company's engineers toward the trouble he encounters in trying to adapt the product to the buyers' needs; nor does he have any good understanding of the difficulties that might be encountered in production or in manufacturing costs were the trucks designed to meet his own ideas. Therefore, the attitude of the service man is one of intense loyalty to his company, with an underlying sympathy for the truck owner. He is enthusiastic regarding any new product of the engineering skill of his employer, until he encounters trouble galore with that product.

How Engineer and Service Man Meet

From my background of experience and observation covering a number of years, let me describe the actions and reactions of an engineer which are all too typical of a condition that, in the interest of the whole automotive industry, demands prompt correction.

After many urgings from the sales department, the chief engineer, feeling that a trip for purposes of intimate contact with the service problems of his own company and his customers is desirable, but a trifle demeaning and somewhat beneath his dignity, delegates to a subordinate the task of field investigation. The subordinate, having locked his desk and his mind, sallies forth with mingled feelings of anticipated pleasure of a trip, with its change from the routine of the drawing-board or desk, and of a rather uneasy premonitory embarrassment over the prospect of having to face some of the practical realities which will no doubt be brought to his attention by one of his company's service managers or his customers, probably both. He has much the mental attitude of one making a long-deferred visit to the dentist, though he fails often to fully comprehend the extent of the cavity.

From the service reports he has received at his office, unfortunately quite devoid of useful information and in keeping with the ostrich-like tradition of the profession, he has a preconceived notion of the service man with whom he plans to confer. He is ever mindful of his own superior education and of the somewhat inferior rank of the practical mechanic from whose forces many of the service managers are drawn. He is smugly unaware of the occasional triumph of practice over theory, and oblivious of the fact that all theory originated in practice.

Consider now the man whom he is to meet. Whether he be an employe of the engineer's own company or a customer, he has been through the hard mill of practical mechanical experience. He, too, is conscious of the superior education of the engineer and has in mind previous didactic correspondence from this engineer. The engineer arrives, bearing a fretful expression and a time-table. The service man is full of his subject, but because of the awe in which he holds the engineer, coupled with the latter's quite evident haste to depart, realizes his inability, in the short time at his disposal, to cover the subjects worrying him. Time is required to warm up a service man sufficiently for him to be at ease and realize that the engineer is not gold-plated, so that they can sit down and discuss their mutual problems on a common ground.

Given insufficient time, the service man is likely to express himself incompletely and inadequately on some one subject, while he is entirely right on many subjects. The engineer is all too prone to remember the subject on which the service man was in error and, reasoning from particulars to general, concludes that the service man is wrong in all matters.

These statements are not intended as a sweeping indictment of the engineer. They are simply an emphatic outline in plain language of a relationship between two highly important departments of the automotive business which is in vital need of improvement. If this relationship is placed upon a proper basis of mutual understanding and tolerance, reinforced by a comprehensive and specific routine for the reporting and correction of mechanical difficulties, it will unquestionably make for the welfare of the producer and the owner alike. True cooperation and genuine progress can be created only upon a foundation of detailed knowledge of and sympathy with the other man's job.

What the Customer Wants and Expects

Having considered a commonly found state of mind of the manufacturer's engineer and his service man, let us give attention to that often neglected and frequently misunderstood man who pays, and pays, and pays: the customer.

Essentially, the intelligent customer demands, with perfect reason, the proper fulfilment of two broad requirements: the fundamental excellence of the product itself and a helpful and continuous relationship with the manufacturer as long as the product remains in the owner's possession.

As for the equipment he purchases, he demands mechanical excellence commensurate with the money he pays; that is, a high value per dollar. He also desires stability of design, with only such changes as will assure keeping pace with genuine improvements, and without the hodge-podge of constant and futile changes many times experienced in this industry, which results inevitably in higher maintenance expense. He demands, though he infrequently gets, a product fitted to the particular needs of his industry and of his operating conditions.

In regard to his relationships with the manufacturer after delivery of the truck, the owner wants primarily

a prompt and effective handling of his service and operating problems as they arise. He has bought more than a mere mechanical product; he has bought motor transportation, and is entitled to the specialized knowledge which the manufacturer has or should have. Therefore, he wants, with good reason, to be relieved as far as possible of the responsibility of exercising the increasingly difficult technique of automotive service. His primary concern is that of manufacturing and distributing petroleum, dairy or other products, or of the proper running of his department store, or the like. In short, he wants a good product and good service in the highest sense of these terms. In this connection, it is appropriate to define service in its application to the proper relationship between the customer and the manufacturer.

Service comprehends both helpfulness preceding the sale and a continued interest after the truck has been delivered. It may even include assistance to the buyer on matters only indirectly connected with the seller's goods. Automotive service should be organized with the end in view of enhancing the value of the customer's investment by prolonging the *profitable* life of the product. In the analysis of the mechanical life of motor-vehicles, to determine the best time for disposal of equipment, and so on, service is a most important consideration. It is obvious that well organized service in this industry is an indispensable adjunct to the marketing program of the manufacturer. This is a highly important consideration in the customer's investigation of what to buy.

Owners Want Contact with Technical Men

Lest I be accused of getting away from the main theme of this paper; that is, the proper relationship between the engineer and the service man, and of necessity their combined relationship with the customer, I want to comment rather definitely upon some factors of importance in connection with the proper execution by the manufacturer's organization of the requirements of the owner.

The fact is obvious that a great deal of the customer's contact with the manufacturer is through the medium of a salesman. My belief is that the salesman exercises, and always will exercise, an important and indispensable function in this industry. I do not decry his worth, but I do want to emphasize the fact that the average salesman, even in the commercial-car branch of the automotive industry, is by no means profound in the knowledge of motor transportation and its problems in spite of the claims made by his employer that the company is "selling motor transportation," not just a mechanical unit. This fact has been verified in my experience time after time by comments, particularly of large customers, to the effect that they would much prefer contacting with the engineer or the service man. This emphasizes, not only the necessity for a better relationship between the customer, the engineer and the service man, but also the crying need of a better process of selecting and training automotive salesmen.

Purchasers of automotive equipment, particularly commercial equipment, are becoming far wiser in these days regarding the problems of transportation than they were previously. They very frequently employ technical men for the handling of their transportation problems; they are distinctly not susceptible to some of the so-called technique of old-time salesmanship; their purchases are more frequently the result of close calculation than of social contact with a salesman.

I have tried in this paper to emphasize the necessity for a closer understanding as between the engineer and the service man of their mutual problems; the necessity for their working hand in hand to a common end. I have endeavored to bring out the fact that no routine relationship, however important, is workable without first creating the proper spirit of tolerance and cooperation. I want now to summarize in some detail my ideas of ways in which both the service man and the engineer have shown undue deficiency, and then to discuss briefly some of the details of the actual routine working relationship that should exist between the engineering and service departments so as to best meet the increasing transportation needs of the owner.

Service Man's Position of Great Importance

Let us consider, first, the service man. He is the go-between of the customer and the manufacturer; he has the routine day-by-day contact with the customer. Of necessity he must have the customer's point of view, although I have known many cases wherein such point of view became warped in his mind to the extent that he neglected some of his obvious and desirable responsibilities to his employer. For example, if a service man were to urge, as he sometimes does, the adoption of every new kink and curve demanded by all of the customers with whom he comes in contact, the result obviously would be a hodge-podge of design and of service problems which would be very detrimental to the entire industry. The service man who intelligently presents the customer's needs and criticisms to his engineering department is doing a real job. This demands a type of ability which is not frequently found. I place the responsibility for this to some extent upon the service man himself, but in greater measure upon the manufacturer, who has not fully realized the importance and increasingly complex technique of automotive service and maintenance and who consequently has not permitted the service man to get out of his "grease ball" habit of mind and into a position the dignity and importance of which are warranted by the nature of the work to be done. By this I mean emphatically that, as a rule, the manufacturer's higher executives are not themselves fully aware of the importance and the vast possibilities for good or evil of a well-organized, intelligently manned service department.

Thus a clear duty devolves upon the engineer to instruct the service man in such of the engineer's technique as is of importance in maintenance work. The service man is rare indeed who really has the ability to use the engineering approach to a maintenance problem; who realizes the tremendous importance of a clear assimilation and analysis of the facts of a given situation, and who can properly translate such facts into constructive recommendations for betterment. The service man who reasons from particular to general and who assumes that, because of one or two specific failures, the whole product is going to pot, is a common phenomenon. Furthermore, let it be emphasized that no service manager should be intolerant of the theoretical, as he so frequently is. The true formula for progress is merely the product of theory and practice, seasoned with common sense, keen vision and an insatiable desire for facts.

In addition, whereas many service men may be splen-

did mechanics, they are grossly ignorant of the other important factors of motor transportation. In common with the salesman and the engineer, they have much to learn if they are to provide themselves with the well-rounded knowledge of transportation problems which should be demanded of them. Hence the necessity of the engineer most carefully instructing his company's service personnel in the details of design and transportation engineering that are of obvious consequence.

Now let us reverse the situation and consider in some detail what the engineer can learn from a competent service man. Why, for example, are certain engineers fearful of the adoption of flat rates for maintenance? If they would pay more careful attention to the maintenance man's problems, to simplicity of design, to accessibility of parts and units; if they would consider the desirability of designing in such a way as to keep the requirements of special tools down to the minimum; if they would more frequently realize that in many cases the installation of an inexpensive but fast-moving part may demand dismantling and assembly labor greatly in excess of that which common sense should dictate, perhaps they would not be so fearful of this bogey of flat rates.

Should Design with Eye to Maintenance

Again, the engineer too infrequently, I believe, is prone to send designs from the drawing-board direct to the production department without proper practical test. I think that one of the most desirable procedures a manufacturer can adopt is that of submitting experimental designs to the service department for detailed comment before releases to the production department are made.

Let the engineer remember that all of these factors just mentioned are of great consequence and sometimes considerably influence the judgment of the prospective purchaser toward the company's equipment.

Let the engineer also bear in mind at all times that too frequent design changes mean higher operating and maintenance costs, and therefore less salability of his company's product. He must search for and find the happy medium between such procedure and the ultra-conservative, unprogressive, stupid policy of failing to keep pace with changing demands of the industry, in the smug assumption that because his product has performed satisfactorily in the past it will continue to be entirely satisfactory in the future.

The engineer can perform a valuable service to the service man, and therefore to the customer, by disseminating common-sense data in regard to the practical advantages of new designs as they come out. He can help greatly by supplying clear and explicit technical information to be transferred to the customer by the service man on interesting and understandable mechanical data sheets. The service man is constituted as the company's mouthpiece on technical affairs to the customer. The engineer must bear his full responsibility of making that mouthpiece a more effective one.

Let the engineer, as well as the service man, fully realize the importance of frequency. The frequency of a new type of demand and the frequency of recurrence of a given mechanical complaint are the keynotes upon which the engineer's action should depend. Many lessons can be learned even by a scrutiny of repair-parts turnovers.

I am convinced, too, that the engineers as a class are failing to make use in their work of a veritable gold mine of constructive information and suggestions which can be had by careful cultivation of comments obtainable from service men and even mechanics. Many practical, workable ideas as to design changes can be obtained from the man in overalls on the shop floor. If 1 good idea out of 25 suggestions is adopted, it pays for the entire procedure for stimulating and tabulating such ideas.

Production Standards Needed by Maintenance Men

Another way in which the engineer can be of great assistance to the service man and therefore the owner is by a careful setting up of correct maintenance standards in reference to clearances and tolerances. This matter has been much discussed in maintenance circles but has received comparatively little attention from many manufacturers. The engineer should do everything he can to help the service man in the adoption of what might be termed standards of production in maintenance work. He should work toward interchangeability of parts as opposed to the necessity for selection, which still exists in many cases. He should bear in mind the advantages of the unilateral system of tolerances. In short, he should assist the service man and the owner to throw away the file, the scraper, and the chisel. Imagine the truck owner's difficulties when the parts problem with your own various models is multiplied by the several makes of truck in his service.

May I emphasize again that the engineer can *learn* from his own service man and from the service men of owners. He must remember that large-fleet owners very frequently have employed, in behalf of their transportation problems, engineers with whom a candid discussion and swapping of ideas will virtually always be found mutually profitable. To the manufacturer's engineers I would say, as a result of my many experiences on both sides of the fence, that such technical men in the employment of owners of large fleets not only know their jobs but very definitely have at heart the welfare of the industry as well as that of their own employers. Take them into your confidence at all times. Remember that working closely with them may very possibly provide an added factor of safety to your own reputation and to the security of your job. Study their cost records and those of your own company's service man. Keep track of their changing problems and of the specific needs of the large truck-buying industries. Good results will be certain to follow.

And remember that one of the chief evils of the average engineering department is procrastination. Bear in mind that hope deferred maketh the owner disgusted, and that a fundamental alertness and resilience of mind which is none too common are demanded of the engineer and the service man alike.

Tripartite Relationships That Should Exist

Now let us give a few moments' further consideration to the purely routine relationships that should exist between the engineer and the service department.

Fundamentally the primary function of the manufacturer's service organization in its relationship with the factory is the dual object of improvement of product and assistance in the important problem of what to make to best fulfill customers' requirements. In both instances the basis of cooperation is the furnishing of

prompt, complete and accurate data from actual field experience, honestly and fairly interpreted and made use of by factory and production engineers. The engineering and production departments which are fortified by a true picture of actual field results will avoid many a pitfall. The requirements of the service department as to simplicity, accessibility and reduction of models to a reasonable minimum are necessarily reflections of the requirements of the owner, and the correct statistical expression of such essentials makes for lower costs and satisfied customers. However, I emphasize again the fact that such reports from the field must be reinforced by personal contact of the engineer with his bread and butter—the customer—and with his service man.

This entire discussion has been largely a recital of the manufacturer's responsibility and his service and engineering obligations to the owner. Seldom does the manufacturer have the courage to thoroughly convince the owner that he, the owner, has a definite responsibility to the manufacturer. This consideration has received far too little emphasis. A closer adherence to the manufacturer's specifications and a more conscientious avoidance of the common evils of overloading, overspeeding, lack of lubrication and deferred maintenance represents an obligation the fulfillment of which is highly profitable to the owner and the manufacturer alike. It cannot be too strongly urged that the owners should make greater use of the facilities and cooperation placed at their disposal by manufacturers and, by the same token, that manufacturers must, in the interests of the automotive industry, better fit themselves to fulfill the additional obligations of service thus imposed. Constructive criticism between the owner and the manufacturer is mutually beneficial.

The burden must be carried primarily by the engineer and the service man working in a spirit of complete cooperation, with a definite and effective routine procedure and with a knowledge and confidence that the ends to be attained are not only in the interests of their own employer, but of the entire automotive industry as well.

A World Language

A WORLD language is certain. Events are pushing resistlessly to compel it. The only question is whether it can be anticipated and given adequate preparation. Whether it is an awkward, hastily devised expedient—perhaps a promising but inadequate instrument like Esperanto—or whether it becomes a master contribution of science to the economical and beautiful handling of ideas, may depend on developments of the next generation. Never has science entered a new field to create order, economy, and unity where before was chaos and conflict, but that it has been bitterly attacked as a base intruder. Never was this more apparent than in the discussion of a synthetic language. The slow growth of usage, traditional scholars claim, is the only road to excellence.

Qualified men can make a critical study of the processes of thinking and of communication, and can synthesize an auxiliary international language of essential simplicity, economy, and beauty—a contribution to the clarity and effectiveness of human thinking that will pass down the ages. The International Auxiliary Language Association of America, with the services of able scholars in varied fields, in a cautious and limited way, is making the beginning of such a study.

Contributions of science to the tools of thought and language may be no less significant than its contributions to the recording and transmission of sound and light.

Whether one's special interest be in art, business or the professions, the finest returns will require sustained effort for critical, open-minded inquiry into causes. The scientific temper is not quickly achieved. Facts and rules memorized, laboratory tasks accomplished, are not science.

The habit of examining the origins of our beliefs and of verifying impressions, persistence in going to authoritative sources, the habit of inquiring whether our opinions are necessary and adequate conclusions from the premises, the development of disciplined skill in observation and reasoning—all this is implied by "the scientific method."—*Antioch Notes.*

The Economic Speed-Weight Relation in Air Transportation

By Edward P. Warner[1]

Cleveland Aeronautic Meeting Paper

Illustrated with Charts

POINTING out that the fundamental object of securing speed, economy, safety and comfort is the same irrespective of the form of transportation used, the author emphasizes the necessity of establishing a balance among these more or less conflicting desirable factors of performance and determining just what that performance may be. The specific basic assumptions upon which the calculations of the paper are made are stated as being that an airplane cruises at 85 per cent of its maximum speed; that two-thirds of the maximum rated horsepower is consumed in level cruising-flight; fuel for a 400-mile flight is carried; the total weight of the powerplant is 2.5 lb. per hp.; weight of the airplane structure is 33 per cent of the total weight carried; and the pay-load is assumed to be two-thirds of the figure remaining after subtracting the structure, the powerplant, and the fuel weight.

The various points covered include the relations of pay-load to engine horsepower, initial cost of airplane and engine, costs per pound of pay-load and per passenger-mile, value of the time saved by greater speed, and the possibilities of increased cruising-speed. Five means for securing higher cruising-speed are listed. A number of charts and tables supplement the paper.

TRANSPORTATION furnished by airplanes continues to be transportation. The fundamental object of securing speed, economy, safety and comfort are the same as in an ocean liner, a railroad train, or for that matter a stage-coach. More speed and less economy are present in the operation of aircraft than in the competing surface vehicles and a different group of patrons is appealed to, but the necessity of establishing some sort of balance among more or less conflicting desirable factors of performance, and of knowing just what that performance is, remains unaltered.

With rare exceptions among those who journey purely for pleasure or for scenic interest, every traveler, other things being equal, would like to get over the ground as rapidly as possible. With no exceptions whatever, every traveler would like, other things being equal, to make his trip as cheaply as possible. Other things never are equal, however, and the operator of a transportation enterprise, in picking his equipment and planning his schedules, must decide just how much economy he can afford to sacrifice to secure increased speed or vice versa.

Obviously, more or less absolute limits are found at both ends of the scale. If the maximum speed of transport between New York City and Chicago, however cheap it might be, were 4 m.p.h., most people would prefer to stay at home. If, on the other hand, the cost were $1,000 for the trip, no rate of speed would build the patronage up to very substantial figures. The exact response that will be elicited from the public by any given combination of speed and economy is of course speculative. It cannot be definitely predicted and in any case it would vary with local conditions. The cost of securing increased speed, however, need not be open to question. It can be definitely calculated for specific examples. At least in approximate terms it can be made the subject of general calculation and of general rules. We must get the figures before we can decide what to do with them or what action to take upon the lesson that they teach.

Basic Assumptions Used

Any generalized calculation depends upon certain assumptions. They may be valid or otherwise in any particular case, but so that the reader can judge for himself of their reasonableness they should at least all be grouped together and clearly stated. For the present analysis we will assume that an airplane cruises at 85 per cent of its maximum speed and that two-thirds of the maximum rated horsepower is consumed in level cruising-flight. Further, we will assume that fuel for a 400-mile flight is carried in every case, and that the total weight of the powerplant, including propeller, starter, and other miscellaneous accessories, but not taking in the tanks, is 2.5 lb. per hp. The weight of the airplane structure will be taken in every case as 33 per cent of the total weight carried. The weight of the tanks will be thrown in with that of the fuel they contain and taken as approximately one-tenth the weight of the contents. The total figure for fuel, oil and tanks is then assumed to be 0.58 lb. per hp-hr., and, with the engine running at two-thirds power during cruising, the weight of fuel to be allowed for will be two-thirds of 0.58, or 0.39 lb. per hr. per rated horsepower. The pay-load in a passenger airplane is assumed to be two-thirds of the residue after the structure, the powerplant and the fuel have been subtracted, the remaining one-third going to cover the crew, the instruments and radio and the interior fittings of the cabin.

Pay-Load per Engine Horsepower

Assumptions concerning costs will be relegated to a somewhat later stage of the paper. With the data outlined in the preceding paragraph, and when given formulas for the minimum and maximum speeds, we can calculate the pay-load per horsepower that can be car-

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ried at various cruising speeds. In this case the calculation has been made for three different minimum speeds; 50, 60 and 75 m.p.h. respectively. The landing speed, owing to ground effect and other causes, would be about 5 m.p.h. below the minimum speed of steady flight in each case for a normal airplane. To tie the characteristics of the airplane up to its performance, the formulas used in Chapter 16 of my book, Aerodynamics of Airplane Design, have been employed.

$$v_{max.} = 127\ (P/S)^{0.39} \quad (1)$$
$$v_{min.} = 17.5 \sqrt{(W/S)} \quad (2)$$

where

P = horsepower
S = area of the wings
v = speed
W = weight of the airplane

These formulas are very far from infallible but have been found to give a satisfactory approximation to the average results with good modern design.

To indicate what all this means as applied to an actual illustration, we may assume a machine having a 300-hp. engine, a total wing area of 360 sq. ft. and a gross weight of 4500 lb. The wing loading would be 12.5 lb. per sq. ft. and the power loading 15 lb. per hp. According to our formula, the maximum speed would be 119 m.p.h. and the minimum speed 60 m.p.h. According to the assumptions previously specified, the weight of the powerplant would be taken as 750 lb.; the fuel, oil and tanks for a 4-hr. flight, 625 lb.; and the structure, 1500 lb. The residue is 1625 lb., of which 1080 lb. may be taken as the pay-load, allowing for five passengers and their baggage together with two pilots. Taking the figures from the minimum-speed formula just given, the permissible wing-loading is found to be 8.5 lb. per sq. ft. for a minimum speed of 50 m.p.h. and 19 lb. for 75 m.p.h. The data can then be arranged in tabular form, as given in Table 1.

In making out the table the spaces corresponding to the highest minimum-speeds and the lowest cruising-speeds have been omitted, as they would give a dangerously low reserve of power. Some of the combinations in the upper right corner of the table, in fact, would not permit of flight at all. To indicate how much reserve would be available for flying at great altitudes and for carrying on in case of the partial or complete failure of an engine, the estimated absolute ceiling of the airplane, determined by the formula, which also is taken from Chapter 16 of Aerodynamics of Airplane Design,

$$H = 40{,}000 \log_{10} [88/(W/P) \sqrt{(W/S)}] \quad (3)$$

has been included in the tabulation. As a rule, a three-engine airplane with one engine dead has a ceiling about 8000 ft. lower than with all three engines running. To permit of getting over rough country, then, in spite of a slight loss of power or the failure of one engine, the absolute ceiling with full power should be at least 10,000 ft. for most transport operations, and all cases corresponding to less than a 6000-ft. ceiling should be absolutely excluded from consideration for passenger carrying.

In Fig. 1 three curves of pay-load per horsepower against cruising speed, corresponding to the three minimum speeds assumed, are plotted. The dotted lines cutting across the series correspond to various assumed absolute ceilings. In Fig. 2 the maximum pay-load per horsepower compatible with a 10,000-ft. ceiling is plotted against the minimum speed of steady flight.

So much for the airplane-design problem, which for the purposes of this paper serves only as an avenue of approach to the economic analysis that is its essential object. The economic phase also involves assumptions as to first cost and as to the annual cost of the equipment. In determining the relation between operating expenses and speed, five elements will be taken as variable. Insurance, depreciation, fuel and oil consumption, maintenance and interest on the initial investment all vary with the power and speed. The other factors making up cost can be considered as dependent only on the aggregate load carried or as pure overhead and entirely independent of the size and the engines and the volume of business done.

Initial-Costs of Airplane and Engine

The cost of the engine, including the propeller, will be assumed to be $14P$. The cost of the airplane, including the instruments, will be taken as $8P + 1.2W$. For the illustration already selected, a seven-passenger airplane, equipped with a nine-cylinder Whirlwind or other engine of equivalent power, that would make the aggregate cost of the engine and propeller $4,200 and that of the airplane, exclusive of engine, $7,800. The latter figure is perhaps a little high for this type of airplane when it has been put in production, but for larger transport machines this formula works out as a reasonably accurate approximation to present levels for both the airplane and its powerplant.

The insurance, including crash protection, will be taken as 16 per cent on the mean value of the airplane during its life, or say 10 per cent on the initial cost.

TABLE 1—DATA ON HYPOTHETICAL AIRPLANE USED IN PAPER

Cruising Speed, M.P.H.	Maximum Speed, M.P.H.	P/S (from formula)	W/P, $v_{min.}$ = 50	60	75	W_{fuel}/P	Weight of Structure/P, $v_{min.}$ = 50	60	75	$W_{residual}/P$, $v_{min.}$ = 50	60	75	Pay Load/P, $v_{min.}$ = 50	60	75	Ceiling, Ft., $v_{min.}$ = 50	60	75
70	82	0.33	26.0	...	...	2.23	8.7	..	..	12.6	..	..	8.4	..	..	2,500	....	....
80	94	0.45	18.9	...	...	1.95	6.3	..	..	8.2	..	..	5.5	..	..	8,100	....	....
90	106	0.61	13.9	20.5	...	1.73	4.6	6.8	..	5.0	9.5	..	3.3	6.3	..	13,400	3,400	....
100	118	0.81	10.5	15.4	...	1.56	3.5	5.1	..	2.9	6.2	..	1.9	4.1	..	18,300	8,300	....
120	141	1.30	6.5	9.6	14.6	1.30	2.2	3.2	4.9	0.5	2.6	5.9	0.3	1.7	3.9	27,000	16,500	5,600
140	165	1.91	4.5	6.5	9.9	1.11	1.5	2.2	3.3	..	0.7	3.0	..	0.5	2.0	.....	23,000	12,300
160	188	2.63	3.2	4.8	7.2	0.98	1.1	1.6	2.4	..	..	1.3	..	..	0.9	.....	.....	17,900

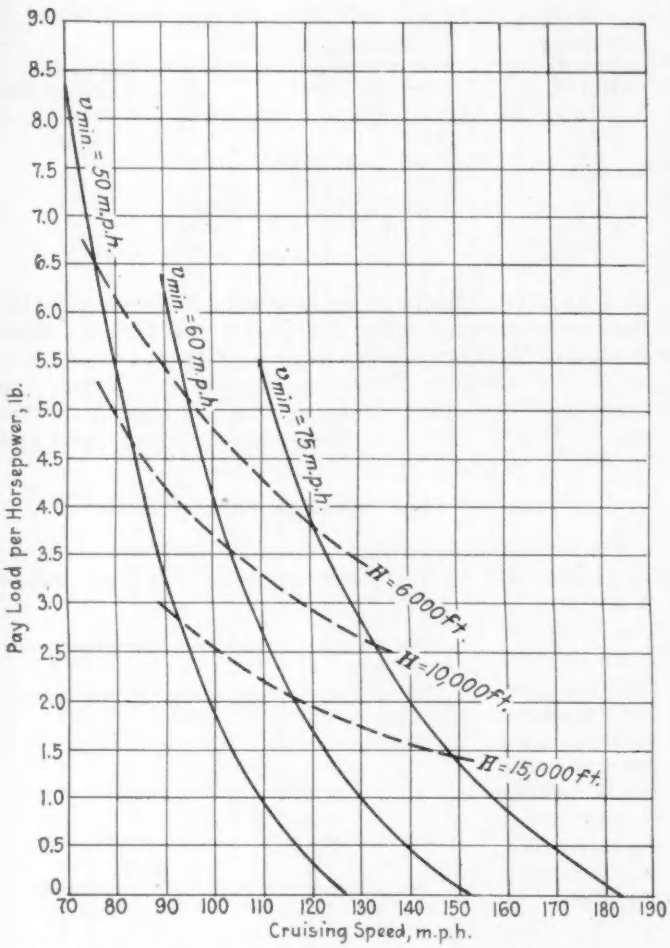

Fig. 1—Relation of Pay-Load per Horsepower to Cruising Speed at Various Minimum Speeds of Flight

Depreciation will be taken as 20 per cent annually on the airplane and 35 per cent on the engine, corresponding to a life of 4 years for the airplane and a little over 2½ years for the engine, with an assumed total flight-time of 800 hr. per year. Interest on the initial investment will be figured at 8 per cent, a rate of return that must be provided by a comparatively novel and unseasoned enterprise.

Fuel and oil will be figured at 2.25 cents per hp-hr. or, when cruising at two-thirds power, at an actual expenditure of 1.5 cents per rated hp. per hr. Maintenance is taken as 0.3 cents per rated hp. per hr. on the engine, and as 0.02 per cent of the initial cost per hour on the airplane structure. To revert to the specific case already used for illustration and to make the figures easier to grasp than they can be in these decimal forms, the unit cost just stated corresponds to a fuel consumption of 17 gal. per hr. at 22 cents per gal. and an oil consumption of 1¼ gal. per hr. at 60 cents per gal. on a 300-hp. engine, with a maintenance cost of \$450 for 500-hr. running on the engine and of approximately \$1,200 per year on the airplane, assuming 800 hr. are flown each year. The latter figure, of course, includes any minor repairs occasioned by accidents falling within the deductable amount of the crash-insurance policy.

In the aggregate, then, the variable factors of cost sum up to

44 per cent per year + 0.02 per cent per hr. for the airplane and

59 per cent per year + 0.13 per cent per hr. for the engine.

Allowing for 800 hr. flying per year, this becomes 0.075 per cent per flying hour on the airplane and 0.20 per cent per flying hour on the engine. Translating these figures into terms of power and weight in accordance with the price formulas already given, they become $0.006P + 0.0009W$ for the airplane and $0.028P$ for the engine, a total of $0.034P + 0.0009W$ per flying hour. Tying these, in turn, to our standard illustrative example, they give a total cost for the variable elements of

$0.034 \times 300 + 0.0009 \times 4500 = 10.2 + 4.05 = \$14.25$ per hr.

Cost per Pound of Pay-Load and Passenger-Mile

The cost per pound of pay-load per hour of flight can then be found by the formula

$$[0.034/(W/P) + 0.0009]\,(W/W_p) \qquad (4)$$

where W_p is the pay-load carried, and the cost per passenger-mile is obtained by dividing by the speed of flight, multiplying by 200, the average weight of a passenger including the standard free allowance of baggage, and dividing by the load factor or ratio of pay-load actually carried to pay-load capacity. The load factor is here taken as two-thirds, which is excellent for any transport enterprise. The results of these calculations are included in Table 2.

The last group of figures is also plotted in Fig. 3 with an arbitrary addition of 9 cents per passenger-mile to correspond approximately to the fixed factors ignored in calculating the magnitude of the variable one. This brings the cost per passenger-mile at a 100-mile cruising speed and a 60-mile minimum speed to a little over 12 cents, which is about the average of the fares on well-established operations at present. Of course, these fixed factors, the large proportion of which correspond to true overhead, are expected to drop substantially as time passes and the traffic increases. In this chart the lines corresponding to ceilings of 6000 and 10,000 ft., the latter being the reasonable minimum and the former the absolute minimum of safe operating conditions, have again been drawn in. These curves of equal ceiling, as will be observed, plot with really extraordinary uniformity as straight horizontal lines. Assuming that a given reserve of power is taken as a fundamental requirement in planning a

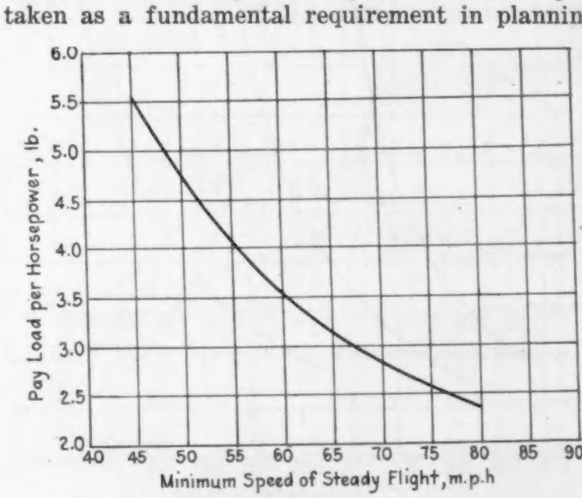

Fig. 2—Maximum Permissible Pay-Load for a 10,000-Ft. Ceiling

TABLE 2—PAY-LOAD AND PASSENGER-MILE COSTS

Cruising Speed, M.P.H.	Cost per Pound of Pay-Load per Hour, Cents			Cost per Passenger-Mile, Based on a Load Factor of 2/3, Cents		
	$v_{min.}=$			$v_{min.}=$		
	50	60	75	50	60	75
70	0.68	...	...	2.91	...	...
80	0.92	...	...	3.45	...	...
90	1.40	0.83	...	4.66	2.76	...
100	2.25	1.16	...	6.75	3.48	...
120	12.00	2.45	1.21	30.00	6.12	3.03
140	...	8.50	2.15	...	18.21	4.59
160	...	...	4.65	...	...	8.72

line, therefore, the minimum operating cost per passenger-mile is virtually independent of cruising speed, or virtually independent of minimum speed, whichever way one may put it. The two limiting speeds, however, are very definitely dependent upon each other, as indicated in Fig. 4, in which they are plotted against each other for the two ceiling heights.

The operator may find expenses per passenger-mile useful units at an intermediate stage of his calculations, but neither to him nor to the passenger is that the unit of ultimate interest. The final comparison is between the fare over a definite route and the time consumed in covering the distance. In Table 3 the total fare and the time have been calculated for a 400-mile run, which may be taken as roughly the distance from Boston to the City of Washington or from Los Angeles to San Francisco. Following in the tabulation, the fares have been plotted against time consumed for the run in Fig. 5. As reminders, the curves of 6000 and 10,000-ft. ceiling are again included.

TABLE 3—FARE AND TIME DATA FOR A 400-MILE ROUTE

Cruising Speed, M.P.H.	Fare for 400 Miles			Time for 400 Miles, Hr.
	$v_{min.}=$			
	50	60	75	
70	$47.60	.....	.....	5.71
80	49.80	.....	.....	5.00
90	54.60	$47.00	.....	4.44
100	63.00	49.90	.....	4.00
120	156.00	60.50	$48.10	3.33
140	.....	108.80	54.40	2.86
160	.....	.....	70.80	2.50

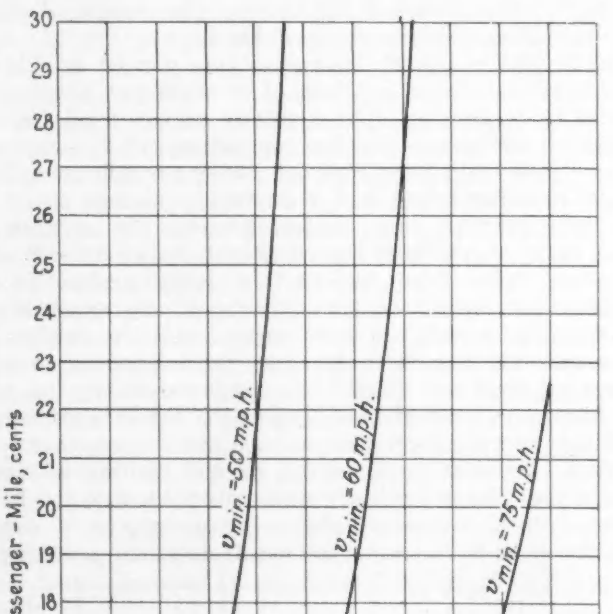

FIG. 3—CURVES OF COST PER PASSENGER-MILE AT DIFFERENT CRUISING SPEEDS

Value of Time Saved by Greater Speed

The next and last step is to reckon with the unit cost of saving time by increasing speed. With the average passenger, that becomes the decisive factor in determining the amount that he is willing to pay for a given ride. In certain cases, of course, the demand for speed is, in the jargon of the economist, absolutely inelastic. To a passenger leaving Cleveland at 10 a.m. to catch a steamer sailing from New York City at 3 p.m., an airplane that lands him at the dock in 5½ hr. is worth just exactly nothing. He might as well walk. One that gets him there in 4¾ hr. may be of great value to him. As a general average, however, and in the long run, a group of individuals set a more or less constant value on saving a unit of time out of their business day. What that value is perhaps lies in the domain of the psychologist and the expert in public relations rather than in that of the economist or the engineer to determine. Obviously it varies widely for individuals even from the same class of society. The railroads have set their own figure upon it, for the extra fare on limited trains is, with a remarkably close approach to uniformity, figured at the rate of $1.20 per hr. saved, whether the run be long or short. In that case a certain part of the payment must be attributed to increased luxury as well as to increased speed.

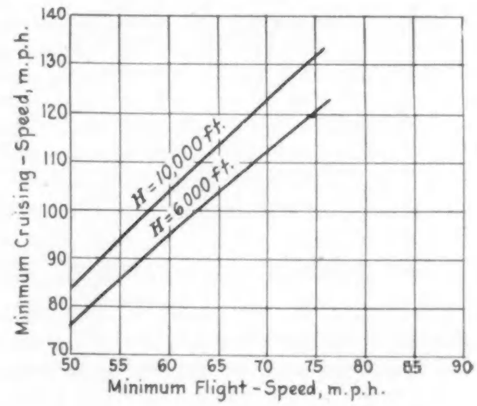

FIG. 4—RELATION OF MINIMUM CRUISING-SPEED TO MINIMUM SPEED OF FLIGHT FOR CEILINGS OF 6000 AND 10,000 FT.

A comparison of different modes of transport yields several figures. A motorcoach on a 250-mile run between important centers of population takes about 4 hr. longer than an average through train and the fare is about $4 less, equivalent to a charge of $1 per hr. for

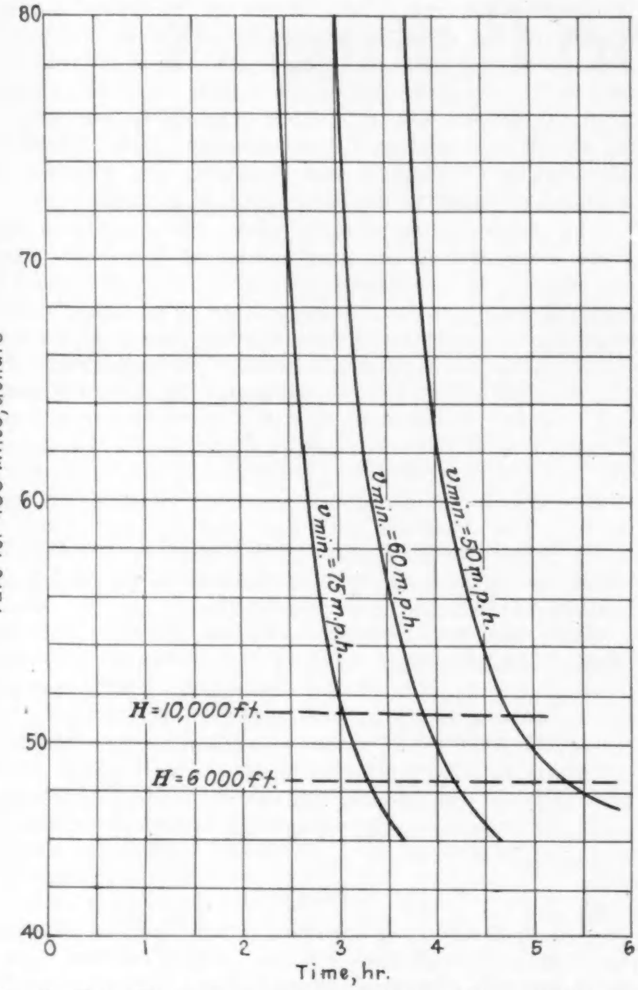

FIG. 5—TIME-FARE CURVES FOR A 400-MILE TRIP AT DIFFERENT MINIMUM SPEEDS

the time saved by the railroad. In going from the railroad to the airplane and making the comparison again on the 400-mile basis, the railroad fare, including Pullman, would be approximately \$16 and that of an airplane cruising at 100 m.p.h. approximately \$50, with a saving in time of about 6½ hr. and a difference in fare at the rate of \$5.20 per hr. saved. This figure is considerably higher than that for the difference between the limited train and the regular train or that between the train and the motorcoach, as is natural, since each increase in speed will somewhat narrow the available range of patronage into successively smaller groups that set successively higher values on their own time.

However, a limit exists to this process. Where the limit lies each man can guess for himself. My own belief is that only a very limited number of travelers are willing to pay at the rate of more than \$10 per hr. saved under ordinary conditions and where they have no fixed and inflexible schedules forced upon them and that the number who would go beyond \$20 per hr. is almost negligible. Whatever the limit may be, the next step is to throw our curves in terms of cost per unit of reduction in time of travel. That can obviously be done by taking the slopes of the curves in Fig. 5 at various points, and in Fig. 6 the results of such a measurement have been plotted. Suppose an air route already in existence, being operated at a definite cruising-speed. New equipment has to be purchased, and the question of whether using higher power and so cutting down the schedule time is worth while must be decided. If the economic situations and habits of the clientele are sufficiently known, Fig. 6 gives the answer.

Possibilities of Increased Cruising-Speeds

If, as an intermediary between the two figures already suggested, \$15 per hr. is assumed to be a reasonable maximum valuation to set on time economy, the maximum cruising-speed that can be recommended ranges from 92 m.p.h. with a minimum flight-speed of 50 m.p.h. up to 133 m.p.h. cruising-speed with a minimum of 75 m.p.h. Higher speeds than these can be obtained only at excessive cost. If higher cruising-speeds are to be realized in practice, and prophecies of 160 to 200 m.p.h. are often heard, it must be done by some one of the following means:

(1) Increasing the aerodynamic efficiency of the design so that the performance formulas used herein will no longer apply
(2) Increasing the structural efficiency, either of airplane or engine, to reduce weights below present practical limits
(3) Reducing such items of expense as insurance and depreciation

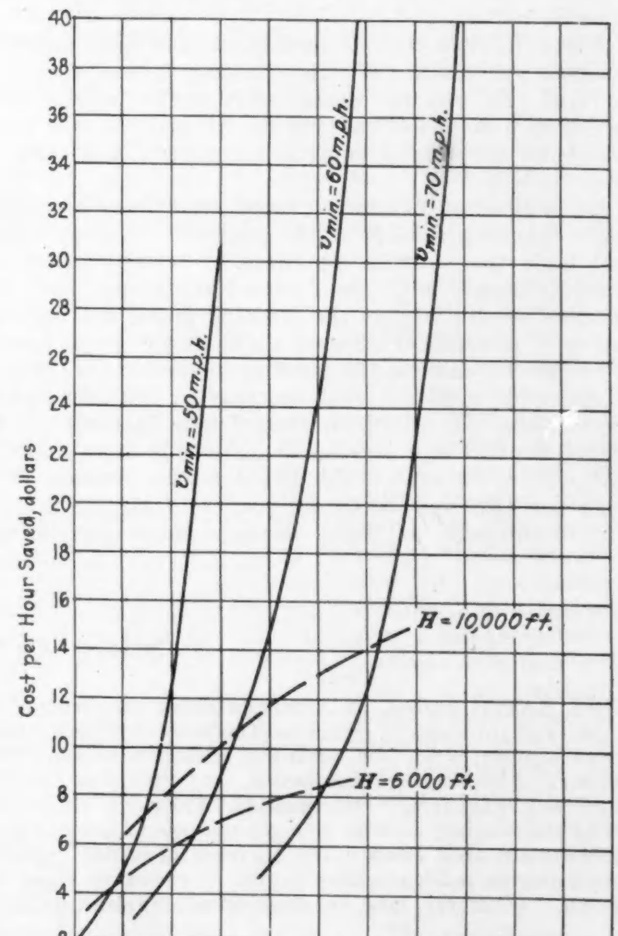

FIG. 6—RELATION OF COST PER HOUR SAVED TO CRUISING SPEED

(4) Using a variable-lift mechanism of some type for the wings
(5) Raising the landing speed

While increasing the aerodynamic efficiency of the design is possible, and of course some progress will be made, improvement here has on the whole been singularly slow. The fact that formulas originally developed in 1922 still define performance with a fair degree of accuracy in 1929 is symptomatic.

The outlook for weight reduction is brighter. Extraordinary advances in reducing engine weight stand to the credit of the last six years. Important improvements in the weight of airplane structure are believed to be probabilities of the near future. Curiously, however, reductions of structural weight have but little effect on the relative economy at different speeds. Any saving that can be made in structural weight will not, in all probability, increase the maximum economical speeds listed herein by more than 4 per cent.

Reduction in items of expense also affords an excellent chance of substantial gain. Insurance rates will certainly come very much lower. Depreciation, too, will drop, although not in the same ratio. Again, however, the final effect proves surprisingly small, with only another 4 per cent of increase in maximum economical cruising-speed if the depreciation and insurance be halved.

Using a variable-lift mechanism for the wings is possible but lies in the indeterminate field of novel invention. As yet no variable-lift device exists that, purely as a means of varying the lift and without some incidental features of control, has shown itself able to "pay its way."

By increasing the landing speed, we at least touch the really startling feature of the analysis. In every curve and table the astonishing effect of landing speed on economy stands out. The faster the landings that are permissible, the higher the cruising speed can be, and the more economical becomes flight at any given speed. A 50-per cent increase in landing speed permits, roughly speaking, a 45-per cent increase in cruising speed. To increase the minimum from 50 to 75 m.p.h. is to reduce the cost of a journey at 120 m.p.h. from a figure that only a Croesus could afford to the modest 12½ cents per mile now becoming conventional.

Unfortunately, as flight becomes more economical, it does not become safer. While the increased landing-speed, if the cruising speed be chosen so as to keep the operating cost per passenger-mile constant, does not entail any lowering of the ceiling or of the proportion of reserve power, it does enhance the dangers of an emergency landing in bad country. It does increase the length of take-off run required and reduces the number of airports available for the airplane's use.

The single-engine airplane never can operate in complete disregard of the possibilities of immediate landing forced by powerplant failure. For the machine with three or more engines, given good maintenance work and an absence of overloading, ignoring such an event should be virtually possible. Suppose, then, that the maximum permissible minimum speed for passenger carrying is taken as 60 m.p.h. with one engine and 75 m.p.h. with three engines. I should hesitate to defend any particular figures very strenuously but believe that those just given stand in reasonable relation to each other. The feasible cruising-speed is then some 22 m.p.h. higher with three engines than with one, provided the airports permit. Even that is a less serious limitation than might be supposed.

While the take-off run increases sharply with increased landing-speed, even at the 75 m.p.h. minimum it reaches only 670 ft. for the power loading corresponding to a 10,000-ft. ceiling. This is, of course, at sea level. At 6000 ft. above the sea the run would be increased to approximately 1100 ft. In taking off at that altitude, continuing flight with one engine dead would be impossible unless enough reserve power were available to give about a 14,000-ft. ceiling.

Summary

In no ordinary case does seeking to operate at cruising speeds of more than 1.8 times the minimum flight-speed appear economically advisable at present. To increase cruising speeds beyond present levels, we must, therefore, increase landing speeds; and the possibility of taking that desirable step depends on the use of engines, engine combinations and maintenance methods that will provide a virtually absolute safeguard against emergency forced landings and upon the provision of airports large enough and smooth enough to permit of landing and taking off at very high speeds without undue difficulty or danger.

School of City Planning

THE RAPID growth of American cities has brought a series of problems in its train. The problem of municipal mis-government is not new, but it still remains unsolved. The problems of housing, transportation, food supply and public health are staggering. Fortunately, American cities are still in the making, so that it is not too late to put comprehensive plans into effect. The increase of urban populations, however much one may regret it, shows no signs of abating. Whatever may be done to aid agriculture and improve rural conditions, the problems of city life will remain of the greatest importance, not only in the sense of physical well being, but also in the very much broader civic sense.

The problems of the city are political, financial, economic, sociological, sanitary, or architectural. All of these fields of investigation are well developed at Harvard. The new School of City Planning there merely ties them together in a new way.—*Harvard Alumni Bulletin.*

Engine-Torque Analysis

By H. A. Huebotter[1]

Annual Meeting Paper — *Illustrated with* Charts

Analytical methods of investigating engine torque are given in this paper, which is an amplification of the method previously presented by the same author, accompanied by a number of sample analyses.

This method is said to be easier to apply to a complete analysis than is the graphical method, and to be adaptable to several types of investigation that cannot be made by the graphical method.

In the discussion is given an outline of the mathematics required to follow the analysis. Electrical engineering students are said to receive instruction in all the mathematics required beyond that used in the graphical method.

Two methods of investigating engine torque were described briefly in the July, 1928, issue of the S.A.E. Journal—the graphical method, submitted by Prof. M. W. Davidson, and the analytical method, by the present writer. The graphical analysis is familiar to the majority of engine designers. Its most commendable feature, which makes it valuable for elementary instructional purposes, is that it visualizes the addition of fluid and inertia forces in each cylinder and the composition of the resulting torques for all the cylinders. When the purpose of the analysis is to determine the engine torque rather than to teach the subject, however, the mathematical treatment deserves recognition by virtue of its greater accuracy, speed, flexibility, and scope. Without attempting to discuss the subject exhaustively, several applications of the analytical method are presented here, with the assurance that its many advantages will be apparent. The derivation of the fundamental mathematical forms can be obtained by reference to P. Cormac's Treatise on Engine Balance Using Exponentials.

The compression and the expansion characteristics of an Otto cycle are shown by the pressure-volume diagram in Fig. 1. The first steps in either the graphical or the analytical process are to determine the positions of the piston corresponding to certain crank-angles, then to measure the fluid pressures at these points for both the compression and the expansion stroke. The similarity of the two methods ceases with these operations.

In the analytical process, the tangential component resulting from the fluid pressure is computed and the results are plotted against crank position, as in the lower part of Fig. 1. This curve shows the tangential fluid-force at the crankpin in pounds per square inch of piston area.

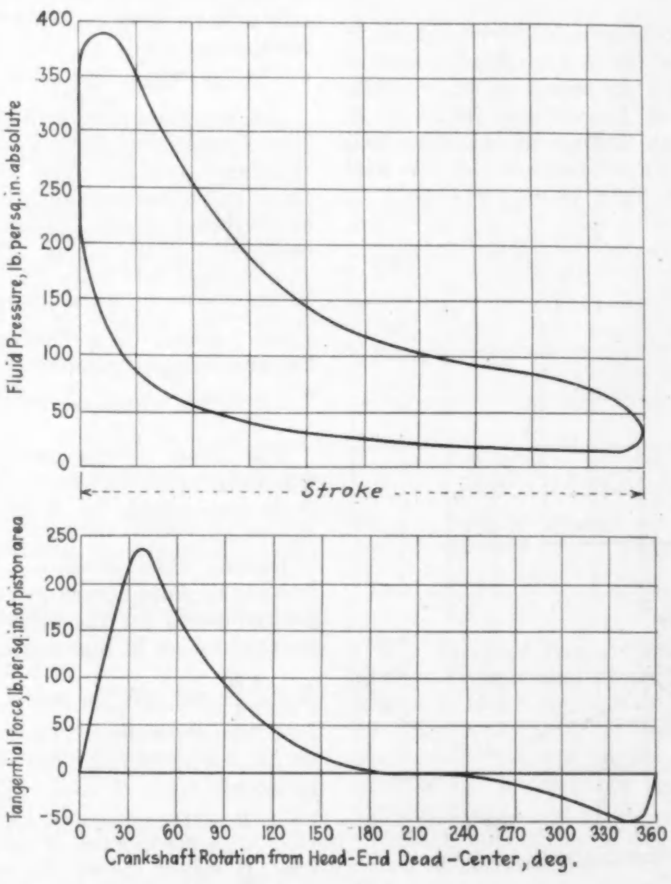

Fig. 1—Compression and Expansion-Stroke Diagrams

In the Lower Half of the Diagram Is Plotted the Tangential Force at Crank Radius Resulting from the Fluid Pressure Shown in the Indicator Diagram Above. It Is a Composite Tangential-Effort Diagram for One Revolution of a Pair of Cylinders Whose Cranks Are in Line

In the conventional multi-cylinder four-cycle in-line engine, the pistons reciprocate in pairs, with their gas cycles 360 deg. apart. For example, if No. 1 piston in a six is on the expansion stroke during the first half of a revolution, No. 6 piston will complete the revolution with the compression stroke. The diagrams in Fig. 1 are therefore composites for a pair of pistons which repeat at every revolution. The other two pairs of cylinders exert similar tangential forces upon the crankshaft, but are out of phase with the first pair by angles of 120 and 240 deg.

The simultaneous ordinates of the tangential-force diagram for all pairs of pistons are combined to give the net fluid-force acting at crankpin radius. The or-

[1] M.S.A.E.—Chief engineer, Butler Mfg. Co., Indianapolis; now research engineer, Waukesha Motor Co., Waukesha, Wis.

dinates could be added graphically, but the mathematical composition of forces leads to certain important advantages which will appear later.

In the analytical summation of tangential forces, the equation of the lower curve in Fig. 1 is expressed as a Fourier series in multiples of the crank angle Θ. In this example, the tangential force at any crank position Θ, in pounds per square inch, is

$$T_f = 38 + 30 \cos \Theta - 13 \cos 2\Theta - 15 \cos 3\Theta - 18 \cos 4\Theta - 15 \cos 5\Theta - 7 \cos 6\Theta + 75 \sin \Theta + 54 \sin 2\Theta + 30 \sin 3\Theta + 17 \sin 4\Theta + 4 \sin 5\Theta \quad (1)$$

The constant 38 is the mean value of the tangential force during one revolution, numerically equal to the indicated mean effective pressure, from the upper diagram of Fig. 1, divided by π. The coefficients of the cosine terms must fulfill the condition that the torque is nil at both dead-centers. The coefficients of the sine terms are checked by taking the algebraic difference between two ordinates of the tangential-force curve that lie equally distant on either side of the head-end dead-center, as for instance the ordinates at 30 and at 330 deg.

As the series contains 12 terms, 12 ordinates uniformly spaced about the crankpin circle are required to establish the coefficients. If the expansion and compression pressures of the indicator diagram are scaled at each 30 deg. of crank angle, the 12 tangential-force ordinates will be derived by computation and the curve need not be plotted.

The addition of the three tangential-force curves in their correct phase-relations for a six-cylinder engine involves T_f, of equation (1), in terms of Θ, $\Theta + 120$, and $\Theta + 240$ deg. The sum of these three values of T_f reduces to a simple equation, owing to the fact that most of the terms vanish. For instance, in the first harmonic, $\cos \Theta + \cos (\Theta + 120) + \cos (\Theta + 240) =$

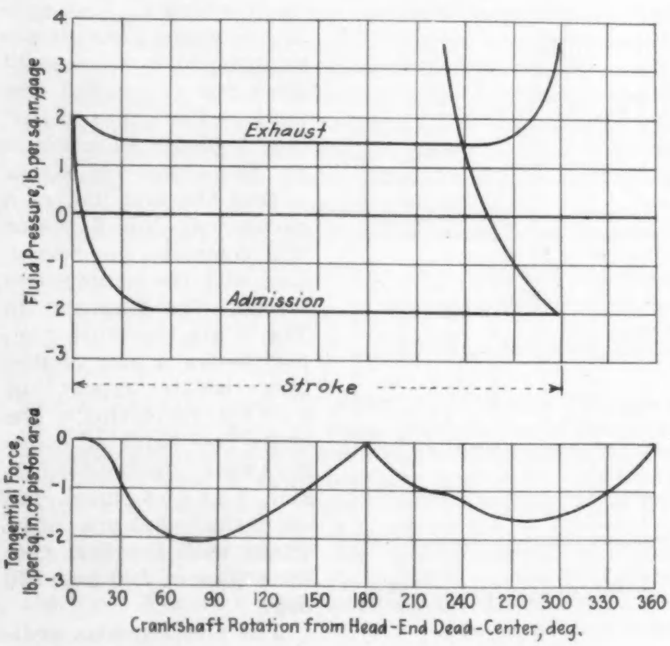

FIG. 2—EXHAUST AND INLET-STROKE DIAGRAMS

These Diagrams, One of Pressure Against Volume and the Other of Tangential Force against Crankshaft Rotation, May Be Combined with the Diagrams in Fig. 1 to Form a Complete Fluid Cycle for a Pair of Cylinders, Which Is Repeated Each Revolution of the Engine

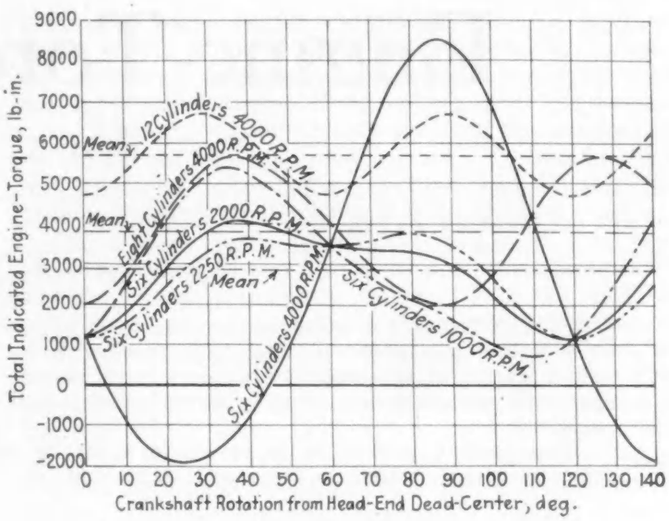

FIG. 3—FULL-LOAD TORQUE CURVES

Cylinders Are 3 9/16 x 5-In. Torque Is Plotted for Six-Cylinder Engines at 1000, 2000, 2250 and 4000 R.P.M. and for Eight and Twelve-Cylinder Engines at 4000 R.P.M. The Fluid Cycle Is as in Fig. 1. The Enormous Kinetic Torque Induced in the Six by High Speed Is Apparent

0. In fact, the functions of all harmonics except those which are multiples of the number of cylinder pairs cancel, and the total unit tangential-force at any crank angle Θ, in pounds per square inch of one piston-head area, is

$$T_6 = 3\,(38 - 15 \cos 3\Theta - 7 \cos 6\Theta + 30 \sin 3\Theta) \quad (2)$$

As the number of cylinders increases, the number of terms remaining from equation (1), after the addition, decreases rapidly. For this reason the small fluctuations in the tangential force of a twelve-cylinder in-line or 60-deg.-V engine is better studied with an equation containing more terms. The 12-term series in equation (1) reduces to

$$T_{12} = 6\,(38 - 7 \cos 6\Theta) \quad (3)$$

when applied to a twelve-cylinder engine, whereas a 24-term series becomes

$$T_{12} = 6\,(38 - 6.67 \cos 6\Theta + 0.08 \cos 12\Theta + 0.5 \sin 6\Theta) \quad (4)$$

The effect of the greater number of terms in the tangential-force equation is negligible in the six, but it is appreciable in studying the minor variations of the twelve.

Having thus developed the method of adding unit tangential fluid-forces, we may write the following general equation for the total fluid-torque, in pound-inches, exerted by an in-line engine which fires uniformly:

$$M = \frac{\pi B^2}{4} RC\,(38 + 30 \cos \Theta - 13 \cos 2\Theta - 15 \cos 3\Theta = 18 \cos 4\Theta - 15 \cos 5\Theta - 7 \cos 6\Theta + 75 \sin \Theta + 54 \sin 2\Theta + 30 \sin 3\Theta + 17 \sin 4\Theta + 4 \sin 5\Theta) \quad (5)$$

in which

B = the cylinder bore, in inches
C = the number of cylinder pairs
R = half the stroke, in inches
Θ = the angle through which the crank has rotated, measured from its head-end dead-center position.

In applying this equation, use only the constant term 38 and the harmonics in multiples of $C\Theta$.

The diagrams in Fig. 1 refer to only two strokes of the cycle. At full load, the inlet and exhaust strokes

have little effect upon the torque, but the resistance of the inlet-manifold depression becomes greater as the load diminishes.

In Fig. 2 are the pressure-volume diagram and the tangential-force curve for the portion of the cycle that is omitted from Fig. 1. These two strokes are handled exactly like the first two. To clarify the mathematical conception, suppose one cylinder to be working on the cycle in Fig. 1 and the other cylinder of the same pair on the cycle in Fig. 2. The unit tangential-force of the pumping cycle, in pounds per square inch, is given by the following expression:

$$T_p = -1.1 - 0.06\cos\theta + 0.79\cos 2\theta + 0.12\cos 3\theta + 0.22\cos 4\theta - 0.07\cos 5\theta + 0.08\cos 6\theta - 0.18\sin\theta - 0.03\sin 2\theta + 0.13\sin 3\theta + 0.07\sin 5\theta \quad (6)$$

The net fluid tangential-force for each pair of cylinders, then, is the sum of T_f and T_p in equations (1) and (6). In practice, the analysis is simplified by adding the simultaneous tangential forces in Figs. 1 and 2, then developing the series to fit their sum. The resulting series is manipulated as prescribed for equation (1), and the full-load fluid-torque for the in-line six-cylinder engine, in pound-inches, becomes

$$M_6 = \frac{3\pi B^2 R}{4}(36.9 - 14.88\cos 3\theta - 6.92\cos 6\theta - 30.13\sin 3\theta) \quad (7)$$

Inertia Torque

The fluid-torque equations define the turning effort of the engine completely at speeds so low that the kinetic forces are negligible, but at high speeds the inertia of the reciprocating parts may have a marked influence upon the instantaneous torque.

In the analytical investigation of inertia torque, the mathematical processes are quite similar to those used with the fluid-pressure torque. For a symmetrical engine in which the connecting-rod length is twice the length of the stroke, the general equation of the total inertia torque, in pound-inches, is as follows:

$$T = 2C\,[0.0000284\,N^2WR^2\,(0.0635\sin\theta - 0.5001\sin 2\theta - 0.1920\sin 3\theta - 0.01612\sin 4\theta + 0.259\times10^{-2}\sin 5\theta + 0.39\times10^{-3}\sin 6\theta - 0.44\times10^{-4}\sin 7\theta - 0.84\times10^{-5}\sin 8\theta + 0.76\times10^{-6}\sin 9\theta + 0.1056\times10^{-6}\sin 10\theta + \ldots\ldots)] \quad (8)$$

in which

C = the number of cylinder pairs.
N = the crankshaft speed, in revolutions per minute
R = half the stroke, in inches
W = the reciprocating weight per cylinder, in pounds
θ = the crank angle, measured from head-end dead-center

Only the functions of the angles which are multiples of $C\theta$ are used.

Total Torque

The net torque is the sum of the fluid and the inertia torques, derived by the addition of equations (5) and (8). Consider an in-line six-cylinder engine in which $B = 3.5625$ in., $R = 2.5$ in., $W = 2.25$ lb., and $N = 2000$ r.p.m. The torque, in pound-inches, is given by the following equation:

$$Q_6 = 7.5\,[1280\,(-0.1920\sin 3\theta + 0.39\times10^{-3}\sin 6\theta) + 10\,(38 - 15\cos 3\theta - 7\cos 6\theta + 30\sin 3\theta)] \quad (9)$$

The torque curve is obtained by plotting this equation between the angles 0 and 120 deg.

In Fig. 3 are illustrated torque curves for the engine of Fig. 1 at speeds of 1000, 2000, 2250, and 4000 r.p.m. One of the advantages in the analytical development of the engine torque is the ease with which the torque characteristics at many speeds can be determined after the calculations have been completed for one speed. The inertia factor 1280, which varies as the square of the speed, is the only numeral in equation (9) that is affected by the transition from 2000 r.p.m. to another speed. This statement is based on the assumption, which is open to criticism, that the same fluid conditions hold for all speeds.

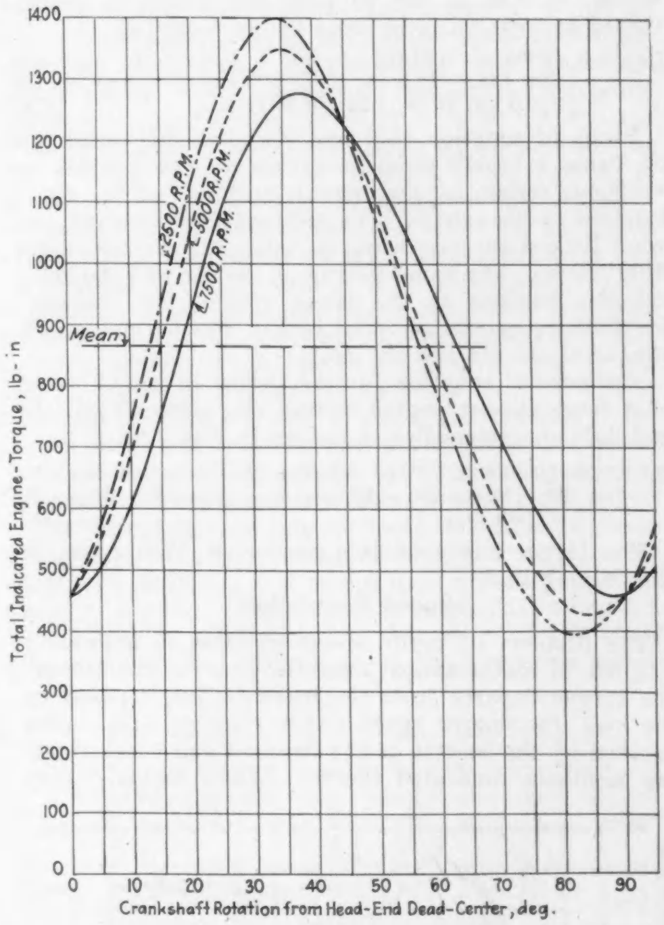

FIG. 4—TORQUE CURVES OF AN EIGHT-CYLINDER RACING ENGINE

This Is Based on a 1.5-Liter Engine Operating on the Cycle of Fig. 1

The full-load torque-curves of an in-line eight or a 90-deg.-V eight and of an in-line twelve or a 60-deg.-V twelve at 4000 r.p.m. are included in Fig. 3, to show the superiority of their inertia-torque balance over that of the six-cylinder engine. The bore, stroke, and reciprocating weight per cylinder are identical in all three engines.

The torque curve of the six-cylinder engine at 2000 r.p.m. illustrates one pitfall that may be encountered in the search for maximum and minimum values by the method explained in the previous article[3]. Although the point 73 deg., 3355 lb-in. is a root of the equation $dQ/d\theta = O$, where Q is taken from equation (9), it is neither a maximum nor a minimum but simply lies in a region of uniform torque. This error can be avoided by

[3] See S.A.E. JOURNAL, July, 1928, p. 107.

examining $dQ/d\theta$ to see if it has the same or opposite signs on each side of the root. The correct minimum is 117.5 deg., 1175 lb-in.

The torque curves of a 91-cu. in. eight-cylinder in-line engine at speeds of 2500, 5000, and 7500 r.p.m. are shown in Fig. 4. The engine is assumed to be supercharged sufficiently at each speed to operate as shown in the indicator diagram of Fig. 1. The unit tangential force is defined by the same 24-term Fourier series as was used for the eight and the twelve-cylinder engines whose characteristics appear in Fig. 3. With a cylinder bore of 2.2 in., a stroke of 3 in., and a reciprocating weight of 0.48 lb. per cylinder, the torque in pound-inches at 7500 r.p.m. is given by the equation:

$$Q_8 = 6\,[2300\,(-0.01612 \sin 4\theta - 0.84 \times 10^{-5} \sin 8\theta) + 3.8\,(38 - 16.9 \cos 4\theta - 1.08 \cos 8\theta + 0.08 \cos 12\theta + 15.0 \sin 4\theta - 1.54 \sin 8\theta)] \qquad (10)$$

Study of equation (10) and Fig. 4 in this paper and of Table 1 in my previous article[2] on the subject reveals one reason for the smooth operation of the eight-cylinder in-line engine. The inertia torque is small, and what little does exist helps to reduce the humps in the fluid torque. The same is true of the six and the four-cylinder engines at the lower speeds, but excessive inertia-torques are possible within the normal speed-ranges of the six and the four.

The general equation for the torque in pound-inches of a four-cylinder engine having the same dimensions and fluid characteristics as the six in Fig. 3 is

$$Q_4 = 50\,[0.000032\,N^2\,(-0.5 \sin 2\theta - 0.0161 \sin 4\theta) + 38 - 13 \cos 2\theta - 18 \cos 4\theta - 7 \cos 6\theta + 54 \sin 2\theta + 17 \sin 4\theta] \qquad (11)$$

The torque curve of this engine at 1850 r.p.m. is shown in Fig. 8.

Speed Regulation

The problem of cyclic speed-variation is admirably adapted to mathematical analysis. As the instantaneous torque departs from the mean torque imposed by the load, the engine speed either rises or falls, being opposed by the inertia of the flywheel and other rotating members connected thereto. When excess energy

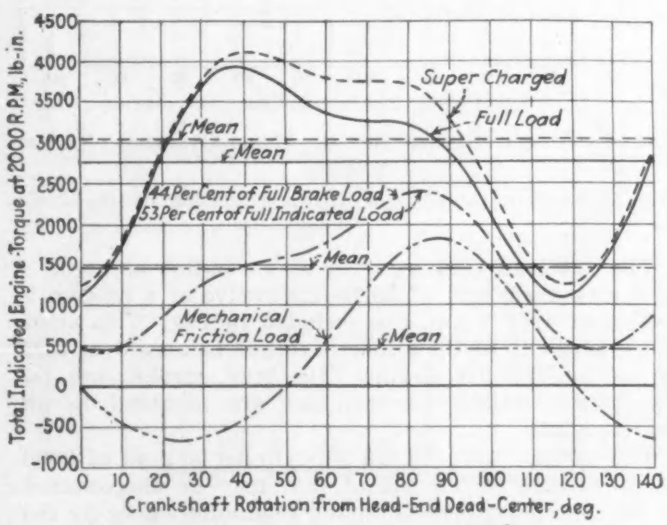

FIG. 5—TORQUE CURVES WITH VARIOUS LOADS

The Full-Load Curve Is the Same as for the Six-Cylinder Engine in Fig. 3. The Upper Curve Is for a Supercharged Cycle with the Compression Pressure the Same as in Fig. 1. The Throttled Cycles Are Based on Admission Pressures 7 and 10 Lb. per Sq. In. Below Atmospheric

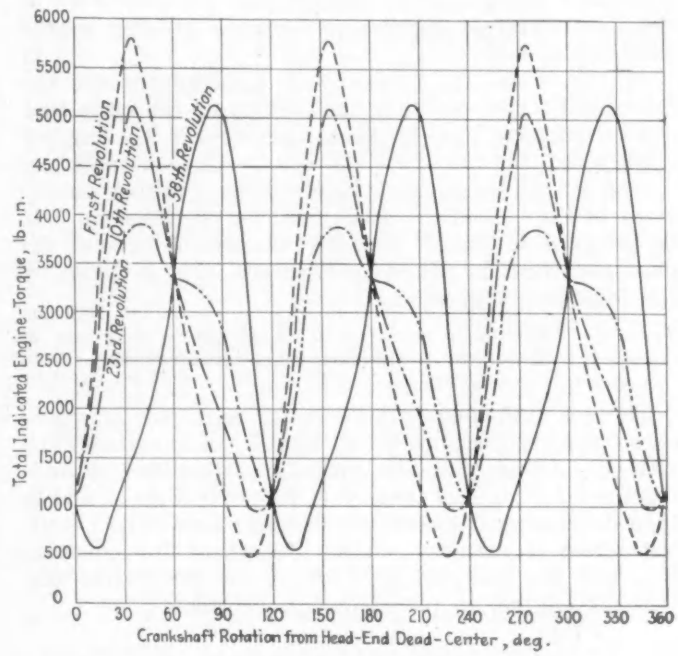

FIG. 6—TORQUE CHARACTERISTICS DURING NO-LOAD ACCELERATION

A Six-Cylinder Engine Is Idling at 200 R.P.M., Then Accelerated with the Throttle Open, without External Load

is being delivered to the crankshaft, it is stored in the flywheel as kinetic energy to be liberated when the engine torque alone is inadequate to carry the load. This storing and release of kinetic energy is accompanied by an increase and decrease in engine speed during each cycle.

The total work done by the torque Q in traversing the small angle $\Delta\theta$ is $Q \cdot \Delta\theta$. If the angle through which the torque Q acts extends from θ_1 to θ_2, the work is expressed by the definite integral

$$W = \int_{\theta_1}^{\theta_2} Q \cdot d\theta \qquad (12)$$

Since the investigation of operating smoothness is concerned principally with the *variation* in torque rather than with its absolute magnitude, equation (12) may preferably be modified to give the excess energy directly.

The fact that the constant term 38 in equation (1) represents the mean unit tangential fluid-effort has already been noted. It follows, therefore, that all the other terms in equation (9) constitute the variations in the torque above and below the mean, since the mean kinetic torque is nil. Hence, if we omit the figure 38 from equation (9) and insert the remaining portion of Q_6 into equation (12), with the proper limits, the resulting integral will represent the difference between the work delivered to the crankshaft and the steady-load requirements.

In Fig. 3, the instant torque at 2000 r.p.m. is equal to the mean torque at both 19.5 and 92 deg. and exceeds the mean between these limits. The excess work performed during this interval, in inch-pounds, is therefore given by the equation

$$E_6 = 75 \int_{19.5}^{92} [128\,(-0.1920 \sin 3\theta + 0.39 \times 10^{-3} \sin 6\theta) - 15 \cos 3\theta - 7 \cos 6\theta + 30 \sin 3\theta]\, d\theta \qquad (13)$$

Solving this expression, $E_6 = 845$ in.-lb. per cycle, which is absorbed in accelerating the flywheel and stored for use during the succeeding interval between 92.0 and 139.5 deg.

The increase in speed from N_1 to N_2 r.p.m., whereby the flywheel acquires the excess energy E, in foot-pounds, is determined by the equation

$$E = \frac{2\pi^2 J}{3600}(N_2^2 - N_1^2) \quad (14)$$

where J is the mass polar moment of inertia of the flywheel, the crankshaft, the clutch, and such other

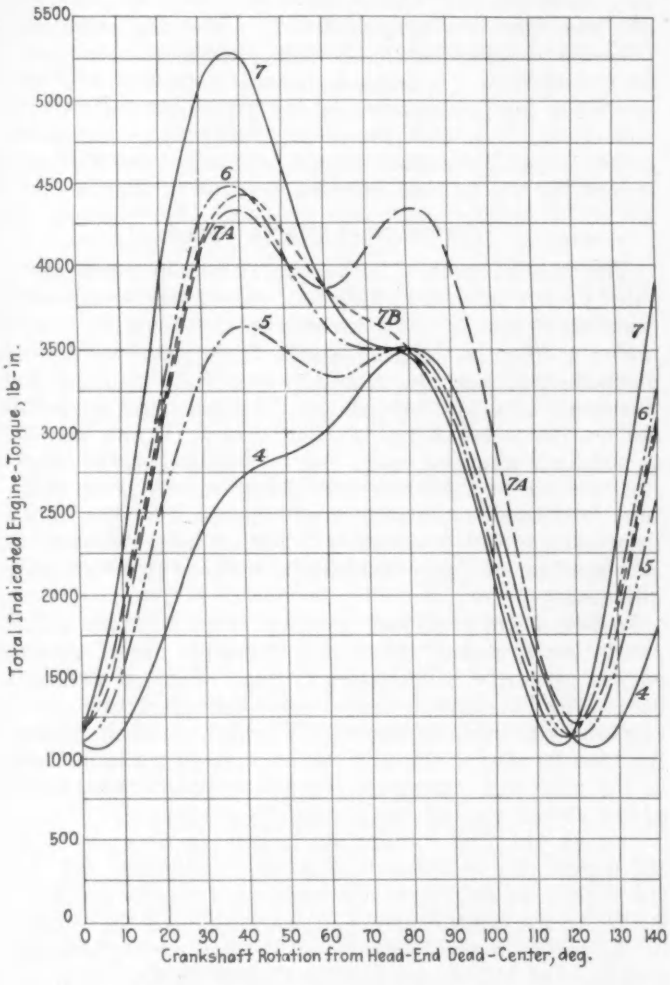

Fig. 7—Torque Curves with Various Compressions

Based on Six-Cylinder 3 9/16 x 5-In. Engine Having Compression Ratios of 4, 5, 6, and 7 to 1, Running at 2000 R.P.M. The Compression Ratios Are Indicated by the Numbers on the Curves. Curve 7*A* Is for a 7:1 Engine at a Speed of 2500 R.P.M. and 7*B* Is for the Same Engine at 2000 R. P. M. with Spark Retarded To Avoid Detonation

parts that rotate together, in pound-feet times seconds squared. In accelerating from N_1 to N_2 r.p.m., the flywheel absorbs 845 in-lb. or 70.4 ft-lb.; in decelerating again to N_1 r.p.m., it releases the same quantity of energy.

If we define the cyclic speed regulation by the ratio $S = N_2 - N_1/N$, where $N = 0.5\ (N_2 + N_1)$, then equation (14) may be rewritten as follows:

$$E = 0.01095\, JN^2S \quad (15)$$

Inserting the known quantities 70.4 ft-lb. for E, 1.33 lb-ft-sec.^{2} for J, and 2000 r.p.m. for N, and solving, $S =$ 0.0012. The total variation in speed is therefore 2.4 r.p.m. three times per revolution. The same analysis applied at the other speeds gives the following results: $S = 0.008$ at 1000 r.p.m., 0.00093 at 2250 r.p.m. and 0.0012 at 4000 r.p.m.

The energy variation during the cycle drops to its minimum value at about 2250 r.p.m., at which speed it amounts to 820 in-lb. The analysis is conducted with the aid of equation (9), wherein the factor 1280 is replaced by $0.00032N^2$. This makes it possible to compute the speeds at which the instant torque is equal to the mean torque for certain assumed values of Θ. In this problem Θ_1 can be allowed to vary between 15 and 30 deg. on the rising side of the torque curve and Θ_2 between 70 and 105 deg. on the falling side. These assumed angles should be plotted against the computed speeds and simultaneous values of N, Θ_1 and Θ_2 selected from the curves. The excess energy E_6 is calculated at the different speeds, as in equation (13), and E_6 is plotted against N to locate the minimum value of E_6.

This method of determining the speed for minimum excess energy and therefore minimum vibration is better adapted to the six than to the four-cylinder engine. When the torque fluctuates above and below the mean value twice per cycle, as it does in the high-torque four-cylinder engines whose curves are given in Fig. 8, the labor involved in finding the optimum speed is double that required for the six. A short and reasonably accurate empirical analysis for determining the speed for smoothest performance in both six and four-cylinder engines is explained in a later section of this paper.

The foregoing analysis of speed variation is based upon the usual erroneous assumption of a rigid crankshaft. Its fallibility will be apparent after a perusal of the later section of this paper on crankshaft vibration. The fallacy in neglecting the distortion of the shaft affects merely the magnitude of the computed speed-

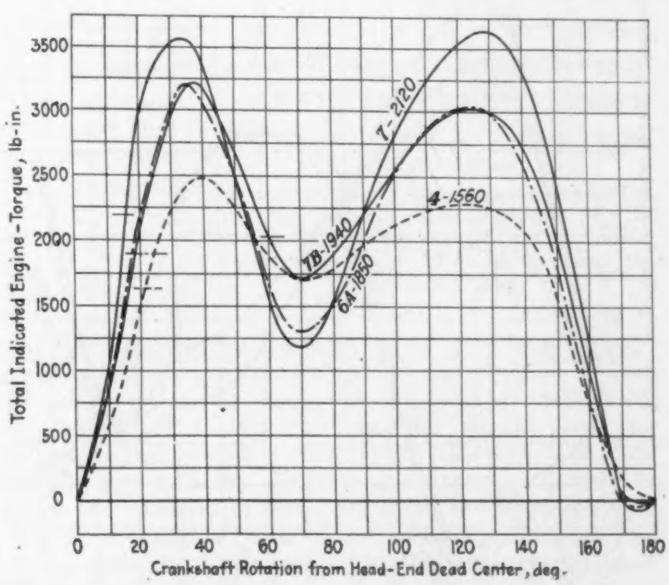

Fig. 8—Lowest Peak Torque-Curves of Four-Cylinder Engine

Curves 4, 7 and 7*B* Are Evolved from the Same Fluid Diagrams as Curves Similarly Designated in Fig. 7. Curve 6*A* Is Based upon the Diagram of Fig. 1. Operating Speeds Are Specified on the Curves

variation and does not preclude the use of the excess-energy value as a criterion in judging comparative roughness of operation.

Torque at Variable Load

The torque curves presented thus far have all dealt with full-throttle conditions and have neglected the losses during the admission and the exhaust strokes. In Fig. 5 are shown four torque-curves of the same six-cylinder engine of which other curves are given in Fig. 3, all taken at 2000 r.p.m. but under four different load conditions. All four strokes of the cycle are included in each analysis. The full-load indicator-diagram is a combination of Figs. 1 and 2, wherein the pumping loss is less than 3 per cent of the net torque.

In the no-load condition, the resistance consists only of the internal mechanical friction, which is found equivalent to an external negative torque of 450 lb-in. and is arbitrarily regarded as constant under all loads at this speed. The cylinder depression during the admission stroke is 10 lb. per sq. in., and the pumping loss is 52 per cent of the net torque, or 234 lb-in. The mean torque represented by the compression and the expansion strokes of the cycle is therefore 684 lb-in.

The intermediate-load curve is based upon a cylinder depression of 7 lb. per sq. in., in which case the pumping loss is only 77 per cent of that at no load.

In the testing of engines with the electric dynamometer, the indicated horsepower usually is taken as the brake horsepower delivered by the engine to the dynamometer when running under load, plus the power delivered by the dynamometer in rotating the engine when measuring the frictional resistance at the same speed. The losses due to both fluid and mechanical resistance are combined under friction horsepower in this interpretation of indicated power, and the indicated mean effective pressure is based upon the compression and expansion diagram only, as shown in Fig. 1. This measured friction horsepower rises as the throttle is moved toward the closed position.

The upper curve in Fig. 5 represents the torque of a supercharged cycle in which a gage pressure of 1.5 lb. per sq. in. is maintained in the cylinder during the admission stroke. The compression ratio in the cylinder has, however, been modified to give the same compression pressure as that with atmospheric induction at full throttle. A suitable torque reduction has been made for the development of the initial pressure in the supercharger, so that the four curves may be considered to represent the engine torque with all losses deducted except the mechanical internal friction of 450 lb-in.

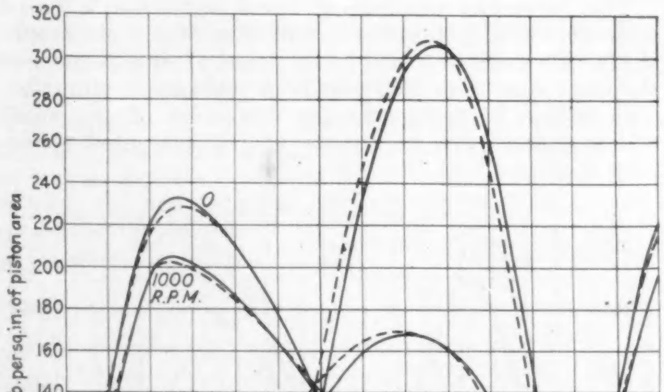

FIG. 9—TORQUES OF SYMMETRICAL AND OFFSET ENGINES

Otherwise Identical Six-Cylinder Engines Are Compared at Full Loads and Different Speeds. Full Lines Represent an Engine Having an Offset Equal to 10 Per Cent of the Stroke

Torque at Variable Speed

The conditions of engine operation discussed up to this point have all included substantially uniform crankshaft speeds. The investigation of engine torque under uniformly varying speeds lends itself readily to mathematical analysis, although it appears to be beyond the scope of graphical solution. Suppose the six-cylinder engine to be idling at a low speed. If the throttle is suddenly snapped open, the full torque of the working medium is absorbed within the engine in overcoming frictional resistance and inertia. If the mean impressed torque is constant for all speeds, the angular acceleration of the crankshaft will be substantially uniform.

In Fig. 6 are four torque-curves, each covering a full revolution but each taken at a different period as the engine responds to the open throttle with no external load. The instantaneous-torque characteristics vary from cycle to cycle as the rise in engine speed augments the kinetic effects. This is apparent from a comparison of the maximum values of the center curves with those of the preceding and the succeeding cycles.

During the first revolution, beginning at a speed of 200 r.p.m., the reciprocating forces are almost nil and the torque is due virtually altogether to the working fluid. At the tenth revolution, the peaks and the valleys in the torque curve begin to show signs of the leveling influence of the reciprocating kinetic forces. During the twenty-third revolution, the torque is still smoother, and the engine should be almost devoid of vibration. But, by the time the fifty-eighth revolution is reached, the speed is so high that the inertia forces dominate the torque characteristics. The vibrating forces at this time have about the same intensity as those during the tenth revolution but they occur 2.3 times as rapidly. Further acceleration imposes stresses of increasing severity upon the engine.

Variable Compression-Ratio

The torque curves in Fig. 7 were developed from modified ideal pressure-volume diagrams. The curves numbered 4, 5, 6, and 7 represent full-load performance at 2000 r.p.m. of four 3 9/16 x 5-in. six-cylinder engines having compression ratios of 4, 5, 6, and 7 to 1, respectively. They differ considerably in their mean torque, maximum torque and excess energy. The pres-

sure-volume diagram for curve 6, for 6:1 compression, is shown in Fig. 16.

Curve 7 indicates somewhat rougher operation than curve 4 but the 7:1-compression engine develops 35 per cent more power than the 4:1-compression engine, and an adequate flywheel can be provided to compensate for the greater torque variations and still maintain a lighter specific weight per horsepower than in the lower-compression engine.

The torque curve 7*A* shows that the high-compression engine should be much smoother at 2500 than at 2000 r.p.m. The excess energy reaches its minimum value of 1000 in-lb. at 2500 r.p.m., whereas at both 2000 and 2900 r.p.m. the energy is 1140 in-lb. The ratio of excess energy to mean energy is identical in curves 7*A* and 4.

These five torque-curves are all based upon combustion at constant volume, the condition for maximum power. Both power and economy increase as the compression ratio rises, since all of the engines have the same volumetric efficiency; but any increase in compression ratio is accompanied by a still greater increase in compression pressure, which invites detonation. Let us assume that a compression ratio of 6 to 1 gives the highest pressure permissible for constant-volume combustion at full load without inducing detonation. This pressure corresponds to approximately 75 per cent of full-load operation with the 7:1 ratio. Above 75-per cent load, the engine will detonate, with normal ignition timing.

But detonation can be suppressed by retarding the ignition, at some sacrifice in power and economy. If the spark occurs so late that combustion is just completed when the piston has traversed 10 per cent of its stroke, the engine power, as shown by torque curve 7*B* in Fig. 7, will be the same as that in curve 6, and detonation may be safely assumed to disappear. The engine with the 7:1 ratio has virtually the same power and economy in the range above 75-per cent load as the 6:1 engine. Below 75-per cent load, where normal ignition timing is feasible, the higher compression-ratio leads to improvement in economy.

Condition for Best Torque

The similarity in shape of the curves 7*A* and 5, in Fig. 7, shows that 2000 r.p.m. is nearly the optimum full-load speed for the 5:1 compression-ratio. Referring to Fig. 3, it is noted that the six-cylinder engine in that analysis was smoothest at 2250 r.p.m. That engine had a compression ratio of 6 to 1 and the same reciprocating weight as the engines in Fig. 7, although the pressure-volume diagram was not ideal. Curve 4, in Fig. 7, indicates that the low-compression engine should run more smoothly at a speed below 2000 r.p.m.

The form of these curves suggests the following proposition: In a six-cylinder engine, smoothest operation is attained when the instant torque is the same at 40 and at 80 deg. This means simply that the kinetic torque must reduce the fluid torque at 40 deg. and increase it at 80 deg. sufficiently to equalize the resultant torque near its two peaks. Since the kinetic torque can be varied by changing either the speed or the reciprocating weight, smooth operation consists largely in correlating the speed and the reciprocating weight to the fluid characteristics.

In the application of this rule, which is purely empirical, the mathematical expression can be derived from equations (5) and (8). The unit tangential force exceeds the mean force by the quantity U_6 in pounds, and U_6 must be the same at $\theta = 40$ and $\theta = 80$ deg.

The equation follows:

$$U_6 = 5.68 \times 10^{-6} N^2 WR (-0.1920 \sin 3\theta + 0.39 \times 10^{-3} \sin 6\theta) - 15 \cos 3\theta - 7 \cos 6\theta + 30 \sin 3\theta \qquad (16)$$

Now, if the values of θ for 40 and 80 deg. are inserted in equation (16) and the results are equated, the cosine terms cancel, since cos 120 = cos 240. Furthermore, sin 120 = sin 240; whence, dividing through by z sin 120 and, simplifying,

$$1.09 \times 10^{-6} N^2 WR = 30 \qquad (17)$$

In general terms, then, for smoothest performance of a six-cylinder engine,

$$1.09 \times 10^{-5} N^2 WR = a A \qquad (18)$$

where a is the coefficient of sin 3θ and A is the area of the piston-head, in square inches.

This speed for the six-cylinder engine of Fig. 3, computed by equation (17), is 2210 r.p.m., which is well within the limits of accuracy attainable by the method described earlier in this paper under the head of speed regulation.

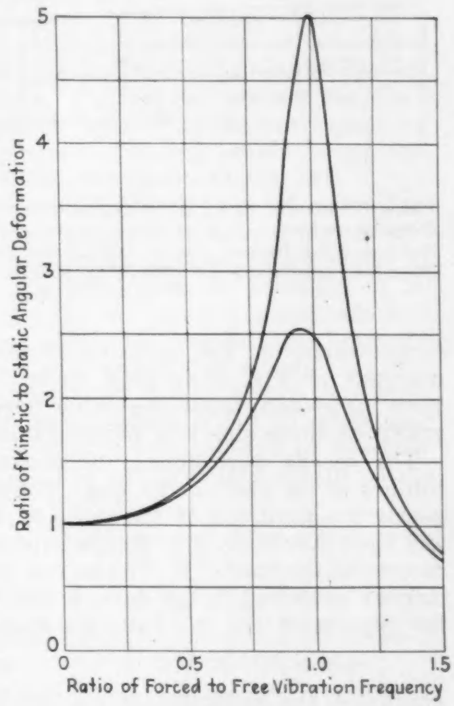

FIG. 10—INFLUENCE OF TORQUE PERIOD AND DAMPING

In the Upper Curve, the Vibration Is Damped to a Resonance Amplitude of Five Times the Static Deformation. The Lower Curve Shows the Effect of Doubling the Damping Factor

If equation (18) is applied to the engines of Fig. 7, the optimum speeds for compression ratios of 4, 5, 6, and 7 to 1 are found to be, respectively, 1740, 2040, 2285, and 2493 r.p.m. In case the engines are intended to be governed at 2000 r.p.m., the reciprocating weight can be adjusted to give the minimum excess energy at full load at that speed. By equation (18), the four engines should have the respective reciprocating weights of 1.70, 2.34, 2.94, and 3.50 lb. per cylinder. This is one exceptional case in which the quantity of metal allowable in the piston may vary in accordance with the service requirements and at the same time improve the inertia characteristics of the engine.

The speed and the reciprocating weight of a four-cylinder engine for smoothest performance can be computed by a somewhat similar method. In Fig. 8 are shown the torque curves of four 3 9/16 x 5-in. four-cylinder engines when running with almost the minimum

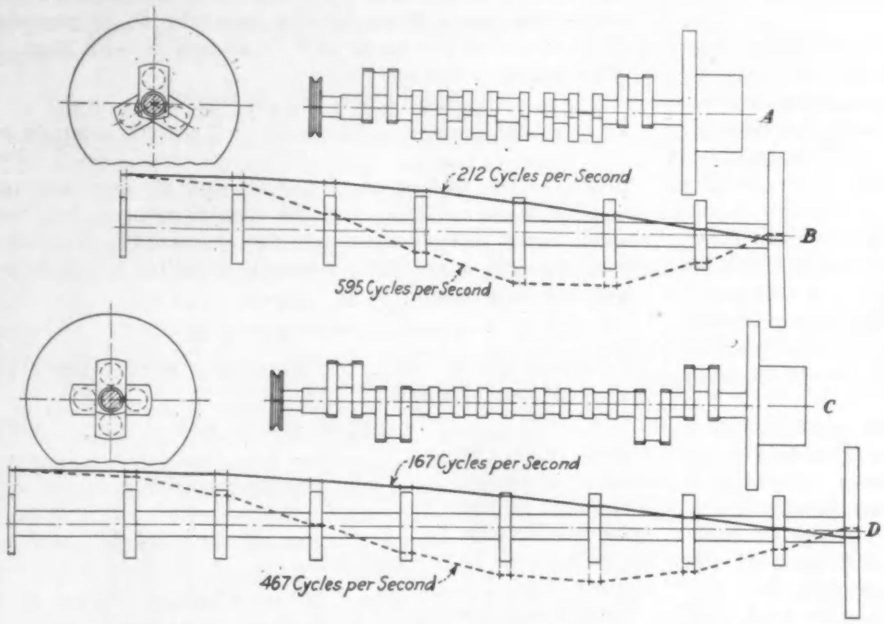

FIG. 11—CRANKSHAFTS AND THEIR TORSIONAL EQUIVALENTS

Conventional Six and Eight-Cylinder Crankshafts Are Illustrated at *A* and *C*, While Their Assumed Torsional Equivalents Are Shown at *B* and *D* Respectively. The Solid and the Broken Curves That Cross the Axes of the Latter Shafts Represent the Relative Amplitudes of Torsional Free Vibration in One and Two Nodes at the Indicated Frequencies

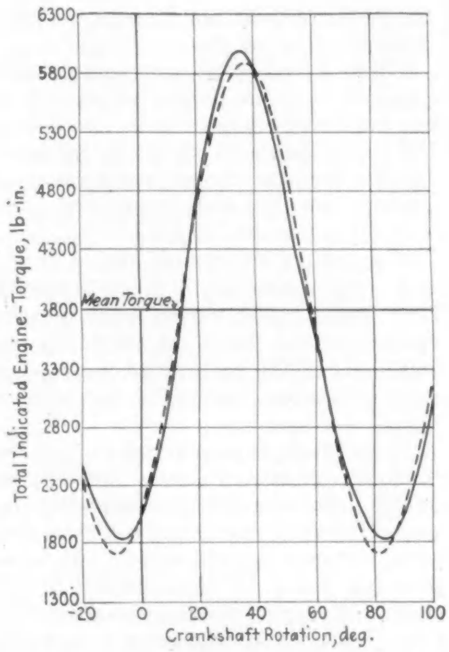

FIG. 12—RELATION OF FLYWHEEL OSCILLATION TO TORQUE CURVE

The Full-Load Torque Curve of the Eight-Cylinder Engine Analyzed in Fig. 3 Is Shown by the Solid Line. The Broken Line Represents the Harmonic Angular Vibration of the Flywheel, Advanced 90 Deg. to Bring It into Phase with Its Disturbing Torque. The Crankshaft and the Torque Are in Tune, with a Frequency of 10,000 Cycles per Minute

torque-variation. The curve 6*A* corresponds to the fluid diagram in Fig. 1 at 1850 r.p.m.; the other curves were developed from the same pressure-volume diagrams as those similarly numbered in Fig. 7.

The speeds were chosen by equating the resultant torques at 30 and at 120 deg. These angles are very nearly the positions of the peaks in the torque curves, and their use leads to a simple expression by which to determine the speed. If the analysis is conducted in the manner explained in the development of equation (18), the expression for the optimum speed is

$$4.92 \times 10^{-5} N^2 WR = A \ (b - 2c + d \sqrt{3}) \qquad (19)$$

where $b =$ the coefficient of $\cos 2\Theta$; $c =$ the coefficient of $\cos 6\Theta$, and $d =$ the coefficient of $\sin 2\Theta$.

If the angles $\Theta = 30$ and 120 deg. are inserted in equation (11) and the resulting expressions are equated, the fourth harmonics cancel, and the simplified form corresponding to equation (19) for a 3 9/16 x 5-in. engine is $1.23 \times 10^{-5} N^2 W = -13 + 14 + 54 \sqrt{3}$. If $W = 2.25$ lb., $N = 1850$ r.p.m. This analysis applies to curve 6*A* in Fig. 8.

The peak of the torque curves actually occurs near 35 deg., but the small change in speed derived from the use of this angle does not justify the added bulkiness in the calculations.

Offset Engines

The torque of an offset engine can also be sloved by analytical methods, although the complex geometry of the crank train makes the analysis somewhat more intricate than that of the symmetrical engine. In Fig. 9 are presented unit tangential-force curves of six-cylinder *désaxé* and symmetrical engines derived from identical conditions of fluid pressure, speed, reciprocating weight, and ratio of crank to connecting-rod. The cylinder of the *désaxé* engine is offset from the crankshaft an amount equal to 10 per cent of the stroke.

An ideal indicator-diagram was used in this analysis so as to eliminate the small mechanical errors incidental to the scaling of a diagram like that in Fig. 1. The fluid-force curve was represented by a Fourier series of 24 terms. The origin of the curves for both engines is at the true head-end dead-center, in which position the crankpin is in line with the piston-pin and the main bearings.

The results indicate that offsetting the cylinder has little effect upon the torque at any speed. The principal advantage in the offset cylinder lies in the reduction of the piston side-thrust during the expansion stroke at low speeds.

Crankshaft Vibration

Reference to the analysis of speed regulation shows that the flywheel of a six-cylinder engine is alternately accelerated and decelerated three times per revolution by variations in engine torque. The crankshaft, being an elastic body, may be expected to obey the physical laws that apply to elastic deformations under the action of external disturbing forces. If the shaft is subjected to angular distortion by a periodic torque applied about its axis of rotation, it will be compelled to vibrate in unison with that torque and at an amplitude that depends upon four factors: the magnitude of the torque; the torsional rigidity of the shaft; the ratio of the torque frequency to the natural frequency of the shaft; and the effectiveness of damping agents.

The quantitative influences of torque period and of damping are illustrated in Fig. 10. Amplitude of vibra-

tion is plotted against the ratio of the frequency of the applied torque to the frequency of free vibration of the shaft. The shaft distortion under a constant torque is taken as unity and is plotted at the abscissa origin. When the torque alternately increases and decreases, the angular deformation of the shaft varies likewise, and the condition is known as forced vibration. The amplitude of vibration increases rapidly as the rate of the torque alternations becomes more nearly in tune with the natural rate of oscillation of the shaft. In the case of identical frequencies or resonance, as at unity on the abscissa scale, the shaft seems to lose its rigidity and the amplitude is limited only by the damping factors—windage, elastic hysteresis, bearing friction, bearing clearance, mechanical dampers and the characteristics of the engine load. The damping factor in the upper curve of Fig. 10 was arbitrarily chosen to limit the resonance amplitude to five times the static deformation. The lower curve has twice the damping of the upper curve and illustrates the interesting fact that, as the damping increases, the maximum amplitude occurs at steadily lowering torque-frequencies. When the rate of torque reversals exceeds the natural frequency of the shaft, the amplitude drops rapidly.

The curves in Fig. 10 were developed on the hypothesis that the torque acting upon the shaft is a simple harmonic function of the time. The earlier analyses of both fluid and kinetic engine-torque have shown that the total torque delivered to the flywheel may be represented by a series of simple harmonics in multiples of the crank angle θ. But, when the crank is revolving at a uniform speed, θ is a linear function of time, and hence the necessary and sufficient conditions for resonance in a crankshaft, as illustrated in Fig. 10, are present in the conventional engine.

The total torque of a six-cylinder engine is defined in equation (9) by harmonics in 3θ and 6θ. A still closer approximation involves analogous functions in 9θ, 12θ, and so on, although the higher harmonics usually are too small to be serious. The conditions for resonance evidently are present at a large number of engine speeds. Just what these speeds are depends upon the crankshaft.

To show the relation between crankshaft design and critical engine-speed, let us consider a six-cylinder engine whose torque characteristics are similar to those in Fig. 3 and whose crankshaft arrangement is illustrated at *A* in Fig. 11. As a mathematical expedient, let us conduct the analysis with the simpler shaft at *B*, which is assumed to be equivalent torsionally to the actual crankshaft. The end discs have the same mass polar moments of inertia as the fan pulley at the front and the flywheel and clutch assembly at the rear. Each of the intermediate discs has the same inertia as a crankpin, two crank-cheeks, the rotating weight of a connecting-rod, and one-half the weight of a reciprocating assembly, the latter two components concentrated at the crankpin. The shafts between the discs have the same torsional rigidity as the corresponding main journals with their adjacent crank-cheeks and crankpins.

The mathematical analysis reveals two vibration frequencies—212 cycles per sec., with a node at the seventh main journal, and 595 cycles per sec., with nodes at journals 3 and 7. The amplitudes of vibration at all points of the shaft for the two conditions are indicated by the solid and the broken lines respectively. Since the total engine-torque is the resultant of simple harmonic forces which have periods of 1/3, 1/6, 1/9 revolution and so on, it follows that resonance will be established at crankshaft speeds of 1/3, 1/6, and 1/9 of the free-vibration frequencies. The major critical speeds should

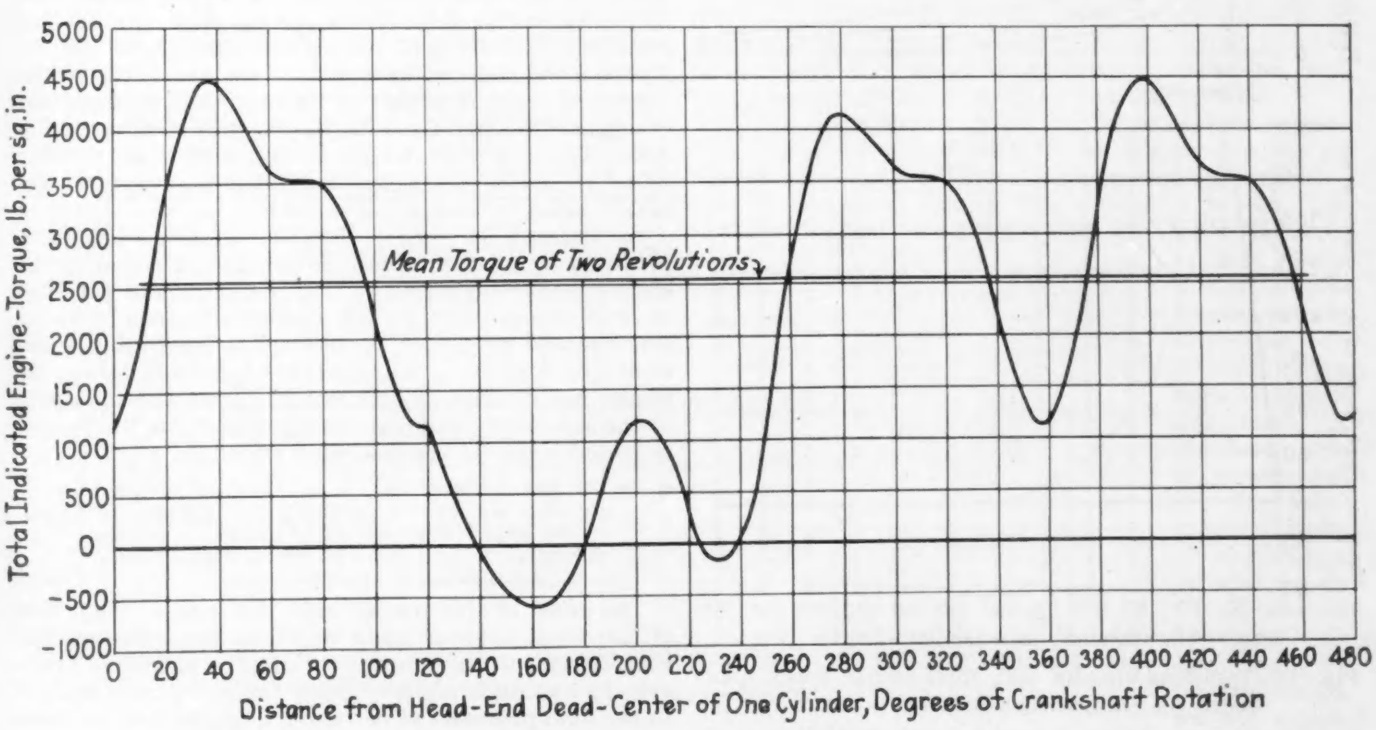

FIG. 13—TORQUE CURVE INCLUDING IGNITION FAILURE

Ignition Failed in the Expansion Stroke Recorded Between 120 and 300 Deg. Other Cycles Are Normal. The Positive Work Between 180 and 225 Deg. Is Performed by the Kinetic Energy of the Two Pistons That Are Decelerating

therefore be in the neighborhood of 1410, 2120, 4240, 3960 r.p.m. and so on. Minor criticals due to harmonic forces that do not contribute to the total torque may also appear. Resonance effects are not severe at the lower engine speeds, for they involve only the small torques of the higher harmonics, but at high speeds the inertia torque may cause a violent threshing of the shaft.

The eight-cylinder-engine shaft in Fig. 11*C* will exhibit critical speeds lower than those of the six for two reasons: the greater length of the shaft leads to a lower free-vibration frequency; and the effective engine-torque has periods of ¼, ⅛, 1/12 revolution and so on, and therefore produces the same torque frequency at lower speed than does the six.

The equivalent cylindrical shaft is illustrated in Fig. 11*D*, with the angular distortions corresponding to the natural frequencies of 167 and 467 cycles per sec. The major critical engine-speeds are, therefore, about 830, 1250, 2500, 2340, and 3500 r.p.m.

The full-load torque-curve for this engine at 2500 r.p.m. appears in Fig. 12. The simple harmonic oscillation of the flywheel is plotted in broken lines on the mean-torque line as an axis, shifted 90 deg. From this it is evident that the torque characteristics are especially favorable for synchronous vibration at this speed.

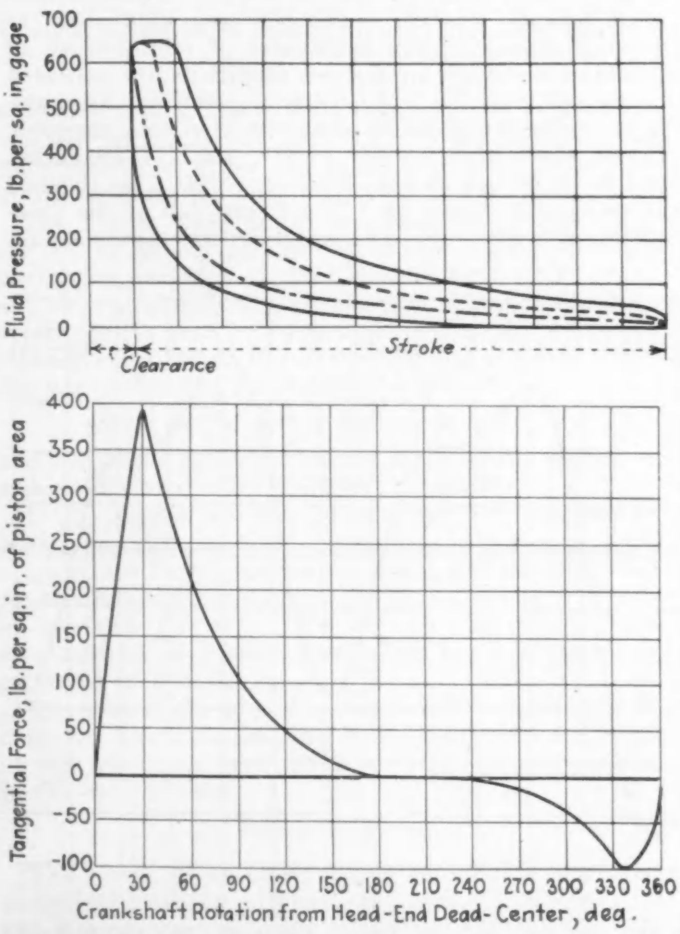

FIG. 14—PRESSURE-VOLUME AND TANGENTIAL-FORCE DIAGRAMS FOR COMPRESSION-IGNITION ENGINE

The Three Pressure-Volume Expansion Curves in the Upper Part of the Figure Are for a Mixed Otto-Diesel Cycle, Representing 25, 75 and 125 Per Cent of Full Indicated Load. The Curve in the Lower Part Shows the Overload Tangential Effort

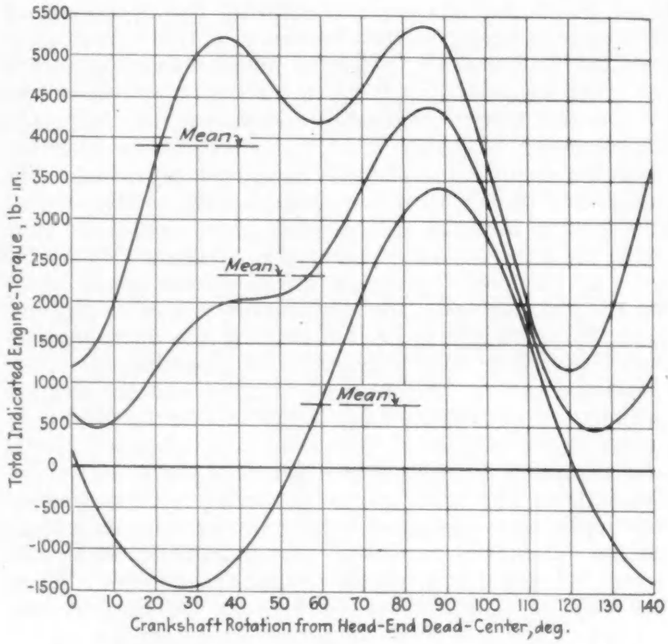

FIG. 15—FULL-PRESSURE TORQUE OF DIESEL ENGINE

Based on Fluid Characteristics of Fig. 14, 3 9/16 x 5-In. Cylinders, 2250 R.P.M. and Reciprocating Weights of 4.75 Lb. per Cylinder

The phase angle between the torque and the shaft vibration varies with their relative frequencies, the lag in the shaft being 90 deg. behind the torque in this instance.

The firing sequence and the disposition of the crankpins both have an influence upon the forced oscillation of the shaft. All the harmonics that are not multiples of the number of cylinder pairs cancel before they reach the flywheel, in the process of torque composition as shown in the development of equation (5) for the resultant fluid-torque; but these components set up stresses and deformations within the crankshaft. The torque of each cylinder is transmitted through the crankshaft to combine with the torques of other cylinders. Those torques which do not appear at the flywheel should be neutralized with the least possible delay, to avoid distortion in the shaft.

An example of forced vibration in the crankshaft, produced by certain torque components, is found in the eight-cylinder-engine shaft in Fig. 11*C*, under full load at 4000 r.p.m. The torque exerted by each cylinder every second revolution is obtained by combining equations (5) and (8). Eliminating the cosine terms, by proper modification of both the coefficient and the angle of the sine terms, reduces the expression for the torque in pound-inches to the following simplified form:

$$Q = 25\ [38 + 96.0 \sin(\theta + 18 \text{ deg. } 12 \text{ min.}) - 75.1 \sin(2\theta + 10 \text{ deg.}) - 24.3 \sin(3\theta - 38 \text{ deg. } 9 \text{ min.}) + 22.0 \sin(4\theta - 54 \text{ deg. } 24 \text{ min.}) + 15.7 \sin(5\theta - 72 \text{ deg. } 36 \text{ min.}) - 7.0 \cos 6\theta] \quad (20)$$

The effect of this torque upon the angular distortion of the shaft depends upon which of the cylinders are contributing to the torque. Manifestly, only four cylinders in an in-line eight-cylinder engine can be involved in the fluid processes at one time. The positions of these four effective cylinders relative to the flywheel is one factor in determining the amplitude of shaft vibration.

Each harmonic component in equation (20) produces

its own frequency of vibration in the crankshaft. The torque, 2400 sin (θ + 18 deg. 12 min.), induces one complete oscillation per revolution, and the corresponding torques of the four cylinders are cumulative vectorially in accordance with their phase angles. Since the cylinder cycles succeed one another at intervals of 90 deg., the resultant torque due to this term is nil at the flywheel, but the crankshaft is subjected to vibration by reason of the non-coincidence of the four torques along the shaft.

The fourth harmonic, 550 sin (4θ — 54 deg. 24 min.), does not cancel, for all cylinders are in phase and the resultant torque is four times the magnitude of the individual-cylinder component.

The amplitude of vibration at the forward end of the shaft varies with both the magnitude of the torque and the distance from its point of application to the flywheel. Suppose the firing order with the shaft in Fig. 11*C* to be 1-6-2-5-8-3-7-4. The cylinders which cooperate to produce the maximum distortion in the first-order vibration are Nos. 2, 5, 8, and 3 at one time and Nos. 7, 4, 1, and 6 at another time. The efforts of these cylinders twist the fan pulley through a much greater arc than those of any other combination of four cylinders. Redesigning the engine for a firing order of 1-7-4-6-8-2-5-3 should reduce the full-load shaft vibration at both high and low speeds but requires changing the main-bearing lengths to compensate for the altered bearing-loads. The fourth-order vibration has a smaller amplitude than the first and is not affected greatly by the revision in firing order. The latter shaft also possesses advantages over the original form in the reduction of torsional vibration induced by the second harmonic of the kinetic torque, which is the principal component of the reciprocating-inertia torque.

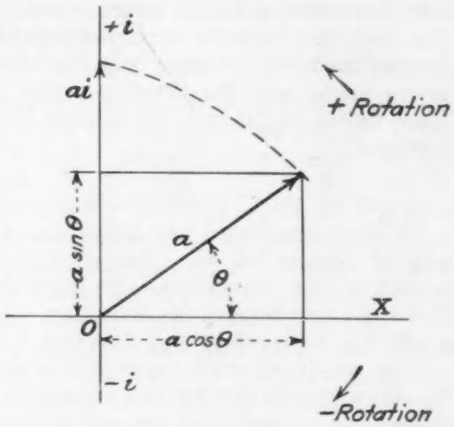

FIG. 17—REPRESENTATION OF A VECTOR

Faulty Ignition

In the preceding analyses, uniformity of fluid processes in all cylinders has been assumed. Such a condition is not essential, although irregularities in the various cycles naturally complicate the investigation of the resultant torque.

Consider the six-cylinder engine in Fig. 7 with the 6:1 compression ratio, running at 2000 r.p.m. If the ignition fails in one cylinder, the other five cylinders must carry the load, and the mean torque drops proportionately. Furthermore, the torque during the expansion stroke of the dead cylinder is almost nil, and the necessary energy is drawn from the flywheel.

In Fig. 13 is shown the torque curve of four successive engine cycles, including the expansion of a charge that failed to ignite. Virtually all the work of compression is recovered during the expansion stroke, but the net energy contributed by the cycle is zero. This condition of engine torque is analyzed as follows: The fluid - tangential force of the dead cycle is represented by the compression stroke of, say, No. 6 cylinder as in Fig. 1 between 180 and 360 deg., plus its inverted image for the expansion stroke of No. 1 cylinder between 0 and

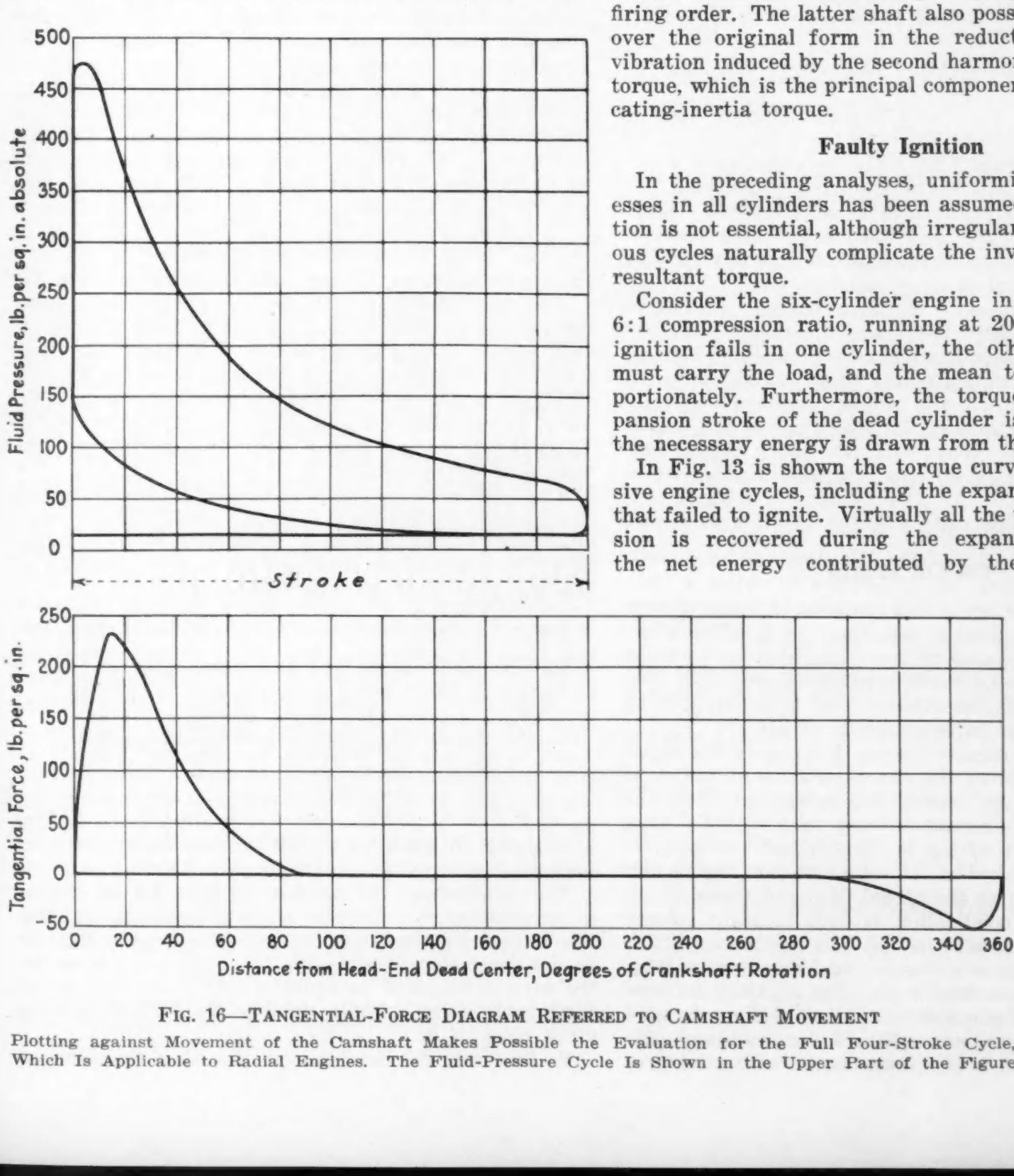

FIG. 16—TANGENTIAL-FORCE DIAGRAM REFERRED TO CAMSHAFT MOVEMENT

Plotting against Movement of the Camshaft Makes Possible the Evaluation for the Full Four-Stroke Cycle, Which Is Applicable to Radial Engines. The Fluid-Pressure Cycle Is Shown in the Upper Part of the Figure

180 deg. Owing to the symmetry of the curve and to the fact that no work is performed, the equation of the tangential force contains only the sine functions of the crank angle, and the Fourier series for the tangential fluid forces in pounds per square inch of piston area, becomes

$$T_f = 19.2 \sin \Theta + 20.3 \sin 2\Theta + 11.7 \sin 3\Theta + 5.7 \sin 4\Theta + 2.3 \sin 5\Theta \quad (21)$$

To this expression are added the values of the tangential forces for the preceding and the succeeding normal cycles, which have the same form although not the same coefficients as equation (1), and in which angle Θ is replaced by $\Theta + 120$ and $\Theta - 120$ deg.

The resultant unit tangential fluid-force acting at crankpin radius during the expansion of the unburned charge, in pounds per square inch of one piston, is given, then, by the expression:

$$T_s = 81.2 - 32.6 \cos \Theta + 12.9 \cos 2\Theta - 33.0 \cos 3\Theta + 19.1 \cos 4\Theta + 16.0 \cos 5\Theta - 17.0 \cos 6\Theta - 58.2 \sin \Theta - 38.7 \sin 2\Theta + 75.9 \sin 3\Theta - 10.0 \sin 4\Theta - 4.0 \sin 5\Theta \quad (22)$$

When all six cylinders are functioning normally, the tangential force, in pounds per square inch of one piston, is

$$T_6 = 3\,(40.6 - 16.5 \cos 3\Theta - 8.5 \cos 6\Theta + 32.1 \sin 3\Theta) \quad (23)$$

The entire 180 deg. of the defective expansion stroke is defined by equation (22), and the remainder of the 720 deg. by equation (23). The resultant inertia and fluid-torque equations are written from equations (8), (22) and (23), as exemplified in equation (9). Manifestly, equations (22) and (23) must give identical values for T_6 at their common points; namely, the beginning and the end of the expansion stroke.

The mean torque with all the cylinders performing their full duty is 3050 lb-in., and the energy variation above and below the mean torque is 80 ft-lb. When one cylinder fails persistently, the mean torque drops to 2540 lb-in. In Fig. 13, the torque curve lies below the mean value for an interval of 162 deg., and the energy deficit is 480 ft-lb. Even with the heavy flywheel assumed in the section on speed regulation, the engine speed will be reduced 17 r.p.m. during this short time and will require 558 deg. of crank rotation to regain its full value.

The Oil Engine

To those who advocate fuel economy through the use of a high expansion-ratio, the Diesel cycle offers alluring thermodynamic possibilities. The high compression of the charge presents no detonation hazards, and complete combustion of the injected fuel is encouraged by the admission of an excess quantity of air.

The composite pressure-volume diagram in the upper part of Fig. 14 shows the characteristics of the cycle at 25, 75 and 125 per cent of full rated load. Only the combustion and the expansion lines vary with the load, since a full charge of air is admitted at every cycle. The diagram is typical of the solid-injection engine and is popularly known as the mixed Otto and Diesel form, since it embodies combustion at both constant volume and constant pressure.

The tangential-force curve in the lower part of Fig. 14 refers to the overload cycle. Its equation is combined with that of the kinetic tangential force to give the resultant torque, as explained for equation (9). For a six-cylinder 3 9/16 x 5-in. engine with a reciprocating weight of 4.75 lb. per cylinder, running at 2250 r.p.m., the torque in pound-inches is defined as follows:

$$Q_6 = 75\,[342\,(-0.1920 \sin 3\Theta + 0.39 \times 10^{-3} \sin 6\Theta) + 52 - 20 \cos 3\Theta - 16 \cos 6\Theta + 65 \sin 3\Theta] \quad (25)$$

This speed, which gives nearly the smoothest performance, was selected with the help of equation (18).

The torque curves at 25, 75, and 125-per cent load are plotted in Fig. 15, whence it appears that the high-pressure character of the diagram in Fig. 14 does not necessarily lead to rough operation. In fact, at 25 per cent overload, the ratio of excess energy to mean energy is practically equal to the average for the six curves in Fig. 7.

The Radial Engine

Engines in which the pistons do not reciprocate in pairs require a variant of the torque analysis hitherto employed. Instead of writing the fluid-tangential-force equation to cover only a single revolution, we must extend it over the entire four-stroke cycle. But, since the trigonometric functions have a period of 2π, the Fourier series which represents the tangential effort must be referred to angles whose range from 0 to 360 deg. covers a complete cylinder cycle. The angle of cam rotation Φ fulfills this requirement and has the advantage of being a definite and not a hypothetical quantity.

The fluid-tangential-force equation for a single cylinder is based on a curve similar to that in the lower part of Fig. 16. This differs from the curves in Figs. 1 and 14 in the use of the cam angle Φ instead of the crank angle Θ in the abscissa scale. Expansion of the products of combustion covers the period from 0 to 90 deg., exhaust from 90 to 180 deg., admission of the new charge from 180 to 270 deg., and compression from 270 to 360 deg. The tangential force is computed at every 30 deg. of crank travel and plotted at every 15 deg. of cam travel. The Fourier series developed from these points will therefore contain 24 terms, of which the first is equal to the indicated mean effective pressure divided by 2π. Such a series represents the curve in Fig. 16 as closely as the 12-term series in equation (1) represents the curve in Fig. 1.

The application of the fluid-tangential-force equation is expedited by reducing it to the form used in equation (20). The following transformation equation serves to combine the sine and the cosine functions of the cam angle into the sine function alone:

$$X \cos \alpha + Y \sin \alpha = (X^2 + Y^2)^{1/2} \sin \left(\alpha + \tan^{-1} \frac{X}{Y}\right) \quad (26)$$

With this modification, the tangential force in Fig. 16 is expressed in pounds per square inch as follows:

$$F = 20.3 + 41.8 \sin (\Phi + 52) + 42.3 \sin (2\Phi + 23) + 38.0 \sin (3\Phi + 2) + 30.2 \sin (4\Phi - 12) + 22.8 \sin (5\Phi - 20) + 18.1 \sin (6\Phi - 27) + 15.05 \sin (7\Phi - 38) + 12.31 \sin (8\Phi - 50) + 9.25 \sin (9\Phi - 61) + 8.60 \sin (10\Phi - 69) + 8.40 \sin (11\Phi - 77) - 4.27 \cos 12\Phi \quad (27)$$

The angles through which the various harmonics have been shifted are given to the nearest degree.

The equation of the resultant torque for an engine of any number of cylinders, firing at uniform intervals, is obtained by combining equations (8) and (27), as in the derivation of equation (9). The expression for the inertia torque T in equation (8) is applied by inserting the total cylinder number for $2C$ and writing 2Φ in place of Θ.

To illustrate the development of such a torque equa-

tion, let us apply the process to a nine-cylinder radial engine with equal cylinder spacing and a single crankpin.

In this engine, all harmonics are balanced except those which are multiples of 9; whence the torque, in pound-inches, is

$$Q_9 = 9R \{ 0.0000284\ N^2WR \times 0.76 \times 10^{-6} \sin 18\Phi + \frac{\pi B^2}{4} [20.3 + 9.25 \sin (9\Phi - 61)] \} \quad (28)$$

Suppose a 3 9/16 x 4-in. nine-cylinder engine to be running at 2500 r.p.m. If the reciprocating weight per cylinder is 2.25 lb., the torque, in pound-inches, is

$$Q_9 = 180\ [80 \times 0.76 \times 10^{-6} \sin 18\Phi + 20.3 + 9.25 \sin (9\Phi - 61)] \quad (29)$$

Since the inertia torque is almost completely balanced, the ratio of torque variation to mean torque is ± 9.25 to 20.3, or ± 45.5 per cent.

In passing, it may be well to note that the moment, in pound-inches, of the counterweight required to balance the reciprocating parts of a radial engine is given by the following equation:

$$J = 0.5\ CRW \quad (30)$$

where C = the number of cylinders, R = half the stroke, in inches, and W = the reciprocating weight per cylinder, in pounds. For the nine-cylinder engine of our example, $J = 20.25$ lb-in.

This method of deriving the expression for the total torque of a radial engine applies to the conventional three, five, and seven-cylinder types. In-line engines that have as many uniformly spaced crankpin-planes as they have cylinders respond to the same analysis.

These examples of the analytical study of engine torque demonstrate the possibilities in the method. The mathematical foundation is neither abstruse nor complex, and the application of the original equations, after they have been derived, is very simple. The saving in time, the gain in accuracy, and the broad range of problems that can be solved by this method should be sufficient inducements to warrant its acceptance.

THE DISCUSSION

Dr. M. J. Zucrow[3]:—Reading this paper of Mr. Huebotter's and then his article and the discussions on the same subject in the July, 1928, issue of the S.A.E. Journal gives me the feeling that Mr. Huebotter's papers are a distinct contribution to the literature on engine mechanics, and that the so-called analytical method which he uses is more complete and flexible than the tedious semi-graphical methods that have been used for so many years.

The issue raised by Mr. Huebotter's paper is not which of two methods for accomplishing the same end is the better; it is whether the time invested in studying and familiarizing oneself with the more complete methods is worth while. Should one learn to use better tools, or is it best to stick to the old tools merely because we know how to use them?

Professor Davidson claimed in his discussion that the analytical method is abstruse. The contrary is true. This method is precise, gives accurate results and, if one is willing to spend the time in studying its development in P. Cormac's book[4], it will be found that most of the work is algebraic. Little advanced mathematics is required for an intelligent comprehension of the subject, and that is presented herewith. The analysis hinges upon the following concepts which, if unfamiliar to the reader, may be taken as fact or their origins may be studied in the aforementioned book:

Concepts on Which Analysis Hinges

A quantity having both magnitude and direction is called a vector and can be represented to scale by a line making the appropriate angle with reference to a given axis; the scale length of the line is the magnitude of the vector, and the angle it makes with the reference axis is its direction. Referring to vector a, in Fig. 17, making the positive angle Θ with OX, we may write the following description of this vector

$$\overline{a} = a\,\overline{\cos}\,\Theta + a\,\overline{\sin}\,\Theta \quad (31)$$

[3] M.S.A.E.—Research associate, Purdue University, Lafayette Ind.; now research engineer, Paragon Vaporizer Corp., Chicago.

[4] See A Treatise on Engine Balance Using Exponentials; E. P. Dutton & Co.

The bars over the component terms indicate that these quantities, added vectorially, will give a. This means that the vector a is the resultant or diagonal formed with $a \cos \Theta$ and $a \sin \Theta$ as adjacent sides.

If we wish to write an expression equivalent to (31) without placing the bars over the components, we write

$$a = a \cos \Theta + ia \sin \Theta = a (\cos \Theta + i \sin \Theta) \quad (32)$$

In (32) the factor i equals $\sqrt{(-1)}$ and signifies that the component $a \sin \Theta$ lies along the i axis and points upward. The multiplication of a term by i is equivalent to rotating it counter-clockwise through 90 deg. The multiplication of a vector by i^2, which equals -1; i^3, which equals $-i$; or i^4, which equals 1, is equivalent to rotating it through 180, 270 or 360 deg. This can readily be verified by substituting these values of Θ in equation (32).

It can be shown that the factor $\cos \Theta + i \sin \Theta$ is equivalent to $e^{i\Theta}$, or

$$a = a (\cos \Theta + i \sin \Theta) = ae^{i\Theta} \quad (33)$$

This proof is simple and need not be repeated here.

If a vector is rotated in the negative or clockwise direction, (33) becomes

$$a = a (\cos \Theta - i \sin \Theta) = ae^{-i\Theta} \quad (34)$$

The following expressions for $\cos \Theta$ and $\sin \Theta$ are obtained from (33) and (34), by addition and subtraction:

$$\cos \Theta = 1/2\ (e^{i\Theta} + e^{-i\Theta}) \text{ and } \sin \Theta = \frac{1}{2i} (e^{i\Theta} - e^{-i\Theta}) \quad (35)$$

If different values are assigned to Θ in (33) and (34), results that can be obtained are $e^{i\pi} = -1$, $e^{-i\pi} = -1$, $e^{i\pi/2} = i$, $e^{-i\pi/2} = -i$, $e^{2\pi i} = 1$, and $e^{\pm 2ki\pi} = 1$, where k is any integer.

The Method Is Not Too Abstruse

The preceding, and the fact that any periodic curve can be represented by a series of sine and cosine terms, called a Fourier series, is all the mathematical preparation required for an intelligent grasp of the subject that is not required for the graphical method. In view of the fact that these concepts are taught to electrical-

engineering students in their courses in alternating-current machinery, I feel that the statement that the method is abstruse is not justified.

The purpose of the analytical method is to present the expressions for inertia force and inertia torque in the form of series of trigonometric terms. This enables combining them readily with any other periodic expression such as the series for fluid torque. It should be pointed out that the labor involved in determining the coefficients of the trigonometric terms in the fluid-torque equation is simplified and greatly reduced by special computation forms devised for that purpose.

One of the commentators on the July, 1928, article states that the analytical method "gives no complete and definite expression for the unbalanced force due to inertia." This is incorrect, for the total unbalanced harmonic of the nth degree, n being any integer, is, in general,

$$F_n = 2\,C\,[0.0000284\,N^2\,WR\,a_n \cos n\,\Theta] \qquad (36)$$

Thus, for the four-cylinder engine discussed by Mr. Huebotter, the unbalanced force in a series which is composed of all harmonics which are integral multiples of the number of pairs of cranks, is

$$F_4 = 4\,[0.0000284\,N^2\,WR\,(0.254 \cos 2\Theta - 0.410 \times 10^{-2} \cos 4\Theta + 0.744 \times 10^{-4} \cos 6\Theta - \ldots\ldots)] \qquad (37)$$

This expression is somewhat more precise than that derived from the usual abbreviated expression for the inertia force of one cylinder[5]. The advantage of the analytical method is that the equation for the resultant reciprocating force for a symmetrical engine of any number of cylinders can be written down at once. In the practical application of the method to design, the coefficients should be determined once and forever for three or four values of connecting-rod length to stroke, and plotted as a series of curves. Intermediate ratios for experimental engines can be interpolated on these curves. This will expedite the analysis of new designs.

The expression for inertia torque can be generalized to read

$$T_i = 2\,C\,(0.0000284\,N^2WR\,b_n \sin n\,\Theta) \qquad (38)$$

Both even and odd harmonics occur in this series, but only those harmonics which are integral multiples of the number of cranks remain unbalanced. Hence, in a six-cylinder engine, the unbalanced inertia-torque is made up of harmonics of orders such as the third, sixth, and ninth. Since b_n is very small except for the third harmonic, the unbalanced torque of a six-cylinder engine is approximately

$$(T_i)_6 = 2\,C\,[0.0000284\,N^2WR\,(-\,0.1920 \sin 3\Theta)] \quad (39)$$

The analytical method is particularly useful in studying the balance of radial, rotary, and oscillating-cylinder engines. P. Cormac, in his book, also develops methods which illustrate the design of coplanar and non-planar crank systems with specified balance. Mr. Huebotter has shown in his paper how the torque equations can be applied to the study of forced vibrations of the crankshaft. His discussion is limited to torsional oscillations but can be readily extended to transverse oscillations. It is interesting to note that Dr. A. Schroder[6] published a few articles on this phase of engine dynamics which embody a good treatment of harmonic analysis and follow the same general plan of attack that Mr. Huebotter advises.

DR. BENJAMIN LIEBOWITZ[7]:—Mr. Huebotter has done a good job. Not only does he justify his claims for the analytical method elaborated by Cormac, but the many numerical examples are useful for reference purposes.

I will agree that, in his hands, the analytical method is superior to the graphical. I almost always prefer the analytical method, but I do not agree that a method can be judged apart from the man who uses it. There are minds with fine physical insight which lack mathematical facility; there are others which reason best after the physical facts have been mathematically formulated; in general, that method is best which best fits the mind which uses it.

Mr. Huebotter has rendered valuable service in preparing this paper, and the value of that service does not depend in any way on competition with other methods.

Graphical Representation Often Desirable

M. W. DAVIDSON[8]:—The scope of Mr. Huebotter's paper is so broad that I am not able, in the limited time available, to present other than a very superficial discussion. The author has very ably presented the wide applicability of the Fourier series to the solution of several problems involving a knowledge of engine torque.

He speaks of the method presented as analytical and refers to the method outlined by myself, in discussing a former paper by him[9] on this subject, as graphical, but it seems to me that both methods partake of the analytical and graphical. There is less appeal to the examination of analytically determined graphs in the author's method, but the method he presents does not obviate the desirability, and in some instances the necessity, for consulting the graphical representation of his calculated results. The opportunity offered for the representation of combined torques through the use of a single mathematical expression appears to be better than the ordinary method of combining the instantaneous torques of a multi-cylinder engine by algebraic addition; yet it is my opinion that the visualization of the calculated instantaneous torques is of great value in suggesting remedies for torque variation.

My chief criticism of the method of attack followed by Mr. Huebotter is that it makes use of a type of mathematical treatment that is not generally familiar to engineers. Still, those who are sufficiently interested in engine design may, if it is necessary, learn the application of the Fourier series to these problems, provided that their mathematical grounding is sufficient.

Inertia Effect of the Connecting-Rod

One phase of vibration upon which the author has not touched should be examined for some types of engine. I refer to the total inertia effect of the connecting-rod. The axial effect of this may be included in the determination of the inertia effect of the reciprocating parts; but, in a complete examination of the vibration, the facts must not be lost sight of that the rod-inertia effect acts through its mass center and that, in addition to the linear effect, the rotative element of the rod's motion produces an angular-inertia effect. In the conventional in-line four and eight-cylinder engines, and

[5] See Mechanics of the Gasoline Engine, by H. A. Huebotter; McGraw-Hill Book Co.

[6] See DER MOTORWAGEN, Dec. 20, 1926, p. 878; July 20, 1927, p. 449; and Aug. 10, 1927, p. 494.

[7] M.S.A.E.—Consulting engineer, New York City.

[8] Professor of mechanical engineering, University of South Dakota, Vermillion, S. D.

[9] See S.A.E. JOURNAL, July, 1928, p. 107.

in the hypothetical in-line twelve with pairs of cranks at 60 deg., the rod-inertia moments and couples are balanced; but, in the conventional in-line six, the angular couples are not in perfect balance.

In a two-cylinder opposed engine, the two angular-inertia rod-couples are additive; and two additional couples are introduced, represented by the two axial and two perpendicular components of the linear inertia of the connecting-rods, which forces act through their mass centers. These rod effects are in balance for all of the in-line engines treated by the author with the exception of the six, and the angular-inertia couples only are slightly out of balance for this. However, consideration of these connecting-rod effects leads to the conclusion that, for certain types of engine, the connecting-rods should have as small moments of inertia as possible.

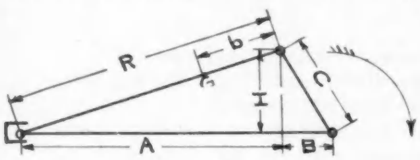

FIG. 18—
DIAGRAM OF RECIPROCATING PARTS

The method employed in the author's paper is on a higher mathematical plane than that outlined in my discussion of his former paper, to which reference has been made, but the Fourier series does not give so exact an expression for the inertia effects as those which I have used, which are given in my paper on Reciprocating Balance of Engines of Six and Eight Cylinders[10]. These expressions are theoretically exact, mathematically simple, and easily applied and understood. Accurate expressions are necessary for a careful study of the inertia effects of the high-speed engine having a small ratio of connecting-rod to crank. The old approximate expressions used for the slow-speed large-ratio steam-engine are not sufficient.

Equations Said To Be More Accurate

The expressions referred to are given herewith, in two forms. In the first form, with constant speed assumed, the only variable is the cosine of the crank angle; and in the second form the angle function is eliminated in favor of the horizontal and vertical projections of the crank and the horizontal projection of the connecting-rod, assuming for convenience that the axis of the engine is horizontal. The first forms are best for calculating forces and couples, but the second forms appear to have value for a detailed examination of the connecting-rod-crank effects.

The expressions for the axial force necessary for the acceleration of the reciprocating parts are

$$F = \frac{WV^2}{g}\left[\frac{R^2\cos^2\phi}{(K + C^2\cos^2\phi)^{3/2}} - \frac{1-\cos^2\phi}{(K + C^2\cos^2\phi)^{1/2}} + \frac{\cos\phi}{C}\right] = \frac{WV^2}{gC^2}\left[\frac{R^2B^2}{A^3} - \frac{H^2}{A} + B\right] \quad (40)$$

For the axial force necessary for the acceleration of the connecting-rod, acting through the rod's mass center, the expressions are

$$F_1 = \frac{W_1V^2}{g}\left[\frac{b}{R}\left(\frac{R^2\cos^2\phi}{(K + C^2\cos^2\phi)^{3/2}} - \frac{1-\cos^2\phi}{(K + C^2\cos^2\phi)^{1/2}}\right) + \frac{\cos\phi}{C}\right] = \frac{W_1V^2}{gC^2}\left[\frac{b}{R}\left(\frac{R^2B^2}{A^3} - \frac{H^2}{A}\right) + B\right] \quad (41)$$

The expressions for the acceleration force of the connecting-rod perpendicular to the engine axis, acting through the rod's mass center, are

$$F_2 = \frac{W_1V^2}{gC}\left[1 - \frac{b}{R}\right](1-\cos^2\phi)^{1/2} = \frac{W_1V^2}{gC}\left[1 - \frac{b}{R}\right]\left(\frac{H}{C}\right) \quad (42)$$

And the expressions for the couple necessary for the angular acceleration of the connecting-rod are

$$M = 4\pi^2N^2IK\left[\frac{C(1-\cos^2\phi)^{1/2}}{(K + C^2\cos^2\phi)^{3/2}}\right] = 4\pi^2N^2IK\left[\frac{H}{A^3}\right] \quad (43)$$

Where, referring to Fig. 18,

G = position of the mass center of the connecting-rod
g = acceleration due to gravity, in feet per sec. per sec.
I = gravity moment of inertia of the connecting-rod
$K = R^2 - C^2$
N = revolutions per second
V = velocity of the crankpin, in feet per second
W = weight of reciprocating parts
W_1 = weight of connecting rod
Φ = Crank angle from head center
Other letters represent lengths in feet

The scope of Mr. Huebotter's paper, comprising so many applications of the Fourier series, and the interesting results he obtains, forcibly suggest the possibilities of such studies and methods in the design of the practically vibrationless engine.

[10] See THE JOURNAL, September, 1927, p. 315.

Variable-Pitch Propellers

By Frank W. Caldwell[1]

Cleveland Aeronautic Meeting Paper — *Illustrated with* Charts, Drawings and Photographs

While much experimental work has been done on the controllable-pitch propeller, complexity of existing devices has prevented their being placed on the market. After reviewing briefly the difficulties encountered, due to propeller and engine characteristics, the author discusses the effect of camber ratio and of angle of attack on the speed at which burble occurs, following this with comments on the efficiency of propellers as static-thrust producers, the use of the method of momentum to compute thrust and the application of adjustable-pitch propellers to supercharged engines.

The causes of the forces required to operate the control adjustments are given as (*a*) friction, (*b*) twisting moments produced by centrifugal force and (*c*) twisting moments produced by air pressure. The second of these is taken up in considerable detail and a mathematical expression is derived, by which this quantity can be evaluated at various stations along the blade and plotted, after which the integration can be carried out graphically.

A method of elastic-stress analysis is given which involves determining the direct centrifugal stress; plotting thrust, torque and bending-moment curves; determining the most highly stressed fibers; and finding the deflection at the various stations by a process of double integration, the mean ratio of the deflection necesary to balance the air pressure by centrifugal force to the deflection that would occur if no centrifugal force were present giving an approximate idea of the relative magnitudes of the elastic and static stresses. While this method is only rough, it serves very well for purposes of comparison and in the author's opinion gives a much better picture of the strength of the propeller than the stress analysis alone.

In conclusion the author points out that with the increase of propeller-tip speeds and engine horsepower the aerodynamic advantages of the controllable-pitch propeller become more important and with improved materials and design, the practical requirements of the problem can soon be met.

Considerable experimental work has been carried out in an effort to produce a thoroughly satisfactory controllable-pitch propeller. Up to the present, however, the complication of existing devices has been considered too great to warrant putting them on the market. Most of the difficulties encountered have been of a structural nature, due to the lack of mechanical engineering development and often due to the effort to make the weight too light.

If the propeller is laid out for the top speed of the airplane so that the various sections have a suitable angle of attack at this speed, it will not function at the highest possible efficiency during climb, because the angles of attack are then considerably increased. If the propeller were to turn at a uniform number of revolutions per minute at top speed and during climb, the angle of attack would be enormously increased during the latter, resulting in very poor L/D for the sections, this feature causing considerable loss in the propeller efficiency even at moderate tip-speeds.

In aviation practice, however, the engine characteristics have considerable bearing upon the performance to be obtained by the use of the adustable-pitch propellers. The true conception of the function of the adjustable-pitch propeller involves a study of the effect of the airplane speed, the engine speed and the slip-stream

[1] M.S.A.E.—Chief engineer, Standard Steel Propeller Co., Pittsburgh.

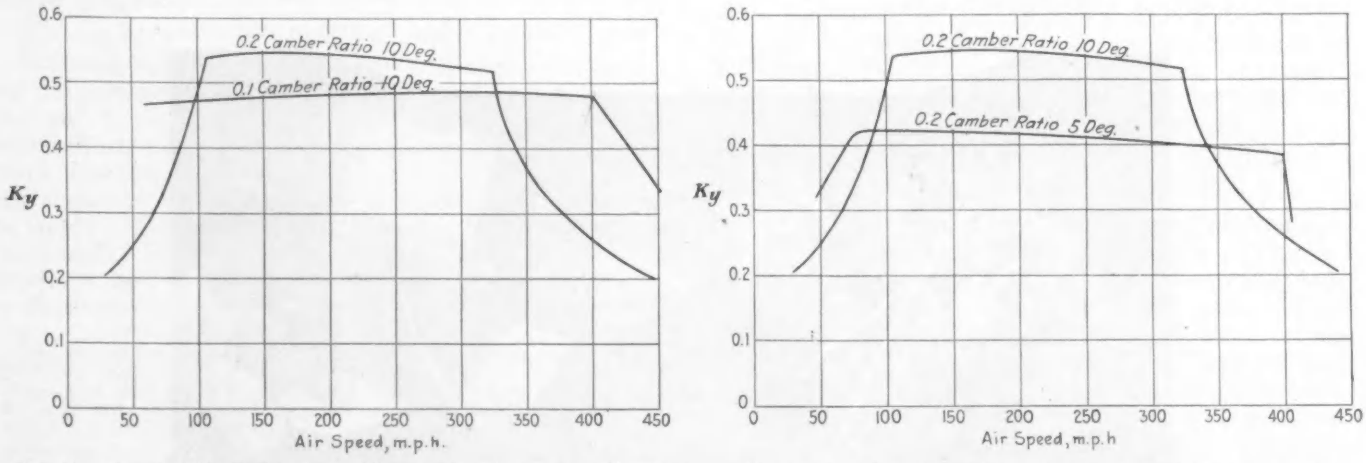

Fig. 1—Curves Showing the Effect of Camber (Left) and Angle of Attack (Right) on the Speed at Which Burble Occurs

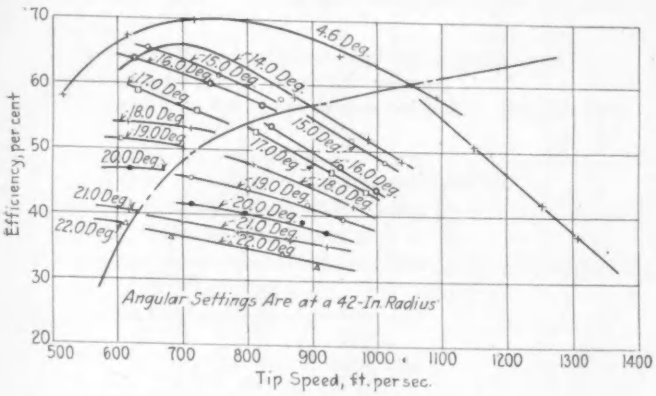

Fig. 2—Efficiency of a Metal Propeller at Various Angular-Settings and Various Tip-Speeds

The Dot and Dash Line Indicates a Tendency toward Discontinuity Which, in General, Occurs at a Higher Velocity for the Lower Angular-Settings.

velocity upon the resulting power delivered by the propeller. The engine speed, as is, of course, well known, is lower during climb than in top speed but does not fall off as rapidly as the airplane speed. At the same time the slip-stream velocity and race rotation are greater during the climb than at top speed, so that the actual change in angle of attack of the fixed-pitch propeller-blade between the top speed and the climbing speed of the airplane is considerably less than might appear at first consideration. Nevertheless, the usual propeller operates at a considerably higher angle of attack during the period of climb than at top speed, and the L/D of the section is correspondingly lower even at low tip-speed.

When we examine this condition from the standpoint of the engine characteristics a somewhat different conception of the function of the adjustable-pitch propeller is reached. As is well known, the brake horsepower delivered by the gasoline engine at full throttle is dependent upon the speed at which it is run and is nearly proportional to the number of revolutions per minute over the range of speeds at which these engines are used in practice. Thus a loss of 10 per cent in the revolutions per minute of the engine between the top speed and the climbing speed will result in a loss of substantially 10 per cent in the power delivered by the engine to the propeller. By the use of the adjustable-pitch propeller we can reduce the angle of attack during climb by reducing the pitch of the propeller and allow the engine to turn up at its maximum safe number of revolutions per minute during climb as well as at top speed.

Camber Ratio, Angle of Attack and Burble Speed

An important feature in connection with the design of controllable-pitch propellers for present tip-speeds is the tendency of the sections used in propeller designs to burble at comparatively low angles when run at very high speed. This tendency has been more or less vaguely studied as tip-speed effect and that a loss in propeller efficiency occurs at high tip-speeds is more or less generally known. This fact alone, however, does not point the way for the designer toward aerodynamic improvements as far as the problem of adapting the propeller design to the airplane and engine is concerned.

A number of years ago E. N. Fales and I ran a series of wind-tunnel tests in which this tendency toward reduction of the angle of burble at high speed was brought out[3]. In these tests we found that (*a*) lowering the angle of attack resulted in raising the speed at which the burble occurred and (*b*) decreasing the camber ratio, or thickness of the section, resulted in raising the speed at which the burble occurred. The left view in Fig. 1 shows a typical test on two sections having camber ratios of 0.1 and 0.2 respectively when set at an angle of attack of 10 deg. The right view presents results of a typical test on a section of 0.2 camber ratio when set at angles of 5 and 10 deg. These charts illustrate, graphically, the effect of camber ratio and of angle of attack on the speed at which the burble occurs.

Propellers as Static-Thrust Producers

In analyzing tests on propellers under static conditions, having a method of comparison that will be related as nearly as possible to the usual definition of efficiency in flight is desirable. The momentum theory offers very simple and convenient basis for establishing the efficiency of propellers as static-thrust producers. For computing thrust by the method of momentum, the custom is to assume that the flow is axial and to ignore the energy of radial and rotational flow. The velocity of airflow into the propeller is also assumed to be one-half of the velocity attained at a point downstream where the static pressure is equal to that of the sur-

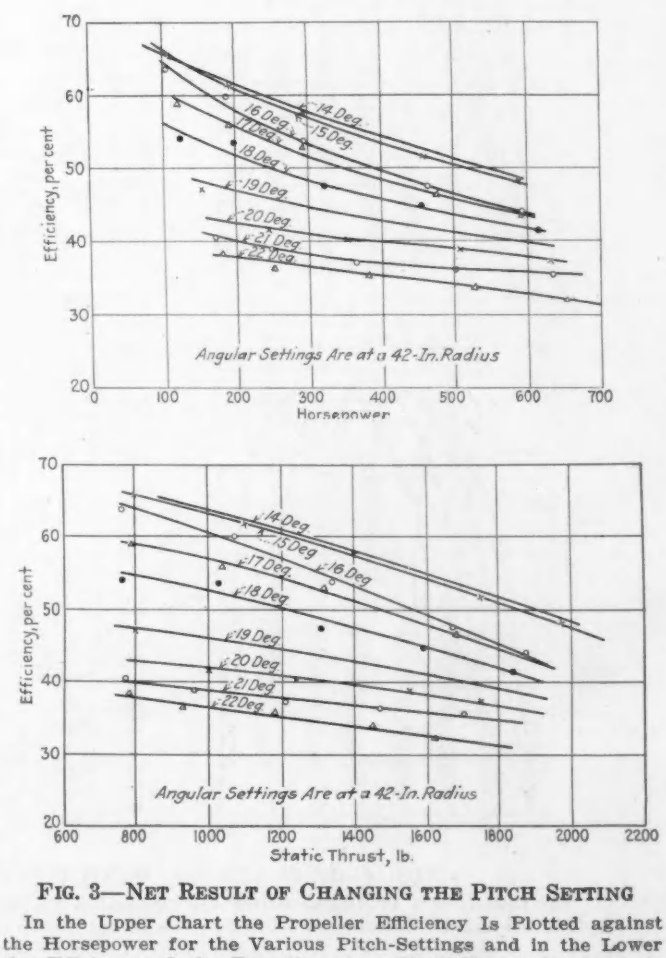

Fig. 3—Net Result of Changing the Pitch Setting

In the Upper Chart the Propeller Efficiency Is Plotted against the Horsepower for the Various Pitch-Settings and in the Lower the Efficiency of the Propeller as a Static-Thrust Producer Is Plotted against the Static Thrust.

[3] See National Advisory Committee for Aeronautics Report No. 83.

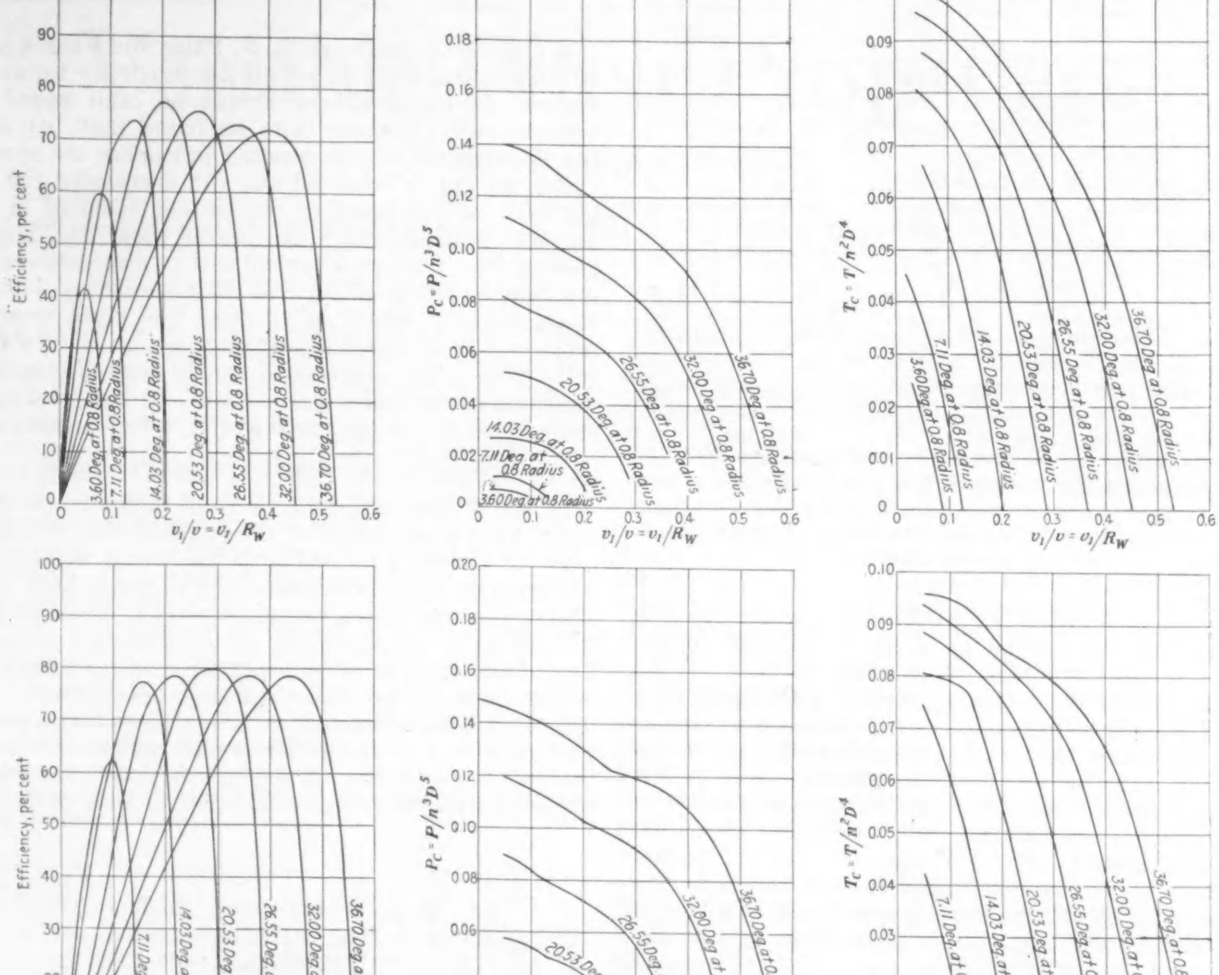

FIG. 4—RESULTS OF WIND-TUNNEL TESTS ON MODEL PROPELLERS

The Results of a Particular Series Are Grouped in the Same Horizontal Row and from Left to Right Show V_1/R_w Plotted against Efficiency, P_c and T_c. The Initial Values of V_1/R_w for the Tests, Reading from Top Down, Are 0.1, 0.2 and 0.3.

rounding air. The relations in foot-pound-second units are as follows:

A = area of the propeller disk in square feet
M = mass of air in slugs per second
P = power in foot-pounds per second = horsepower $\times$ 550
T = thrust in pounds
v = velocity of outflow in feet per second
v_i = velocity of inflow in feet per second

From the momentum equation $T = Mv$.

The energy content of the outflow would be equal to the power absorbed for a perfect propeller, not necessarily a screw propeller,

$$P = \text{Hp.} \times 550 = M\frac{v^2}{2}$$

The thrust per horsepower for an ideal propeller would then be:

$$T/\text{Hp.} = 1100/v$$

The mass of air per second is

$$M = \rho A v$$

where

ρ = slugs per cubic foot or 0.00237 for standard air

Then

$$P = \text{Hp.} \times 550 = \rho A\frac{v^3}{4}$$

$$T = \rho\frac{Av^2}{2}$$

$$v = \sqrt{(2T/\rho A)}$$

$$v = \sqrt[3]{(2200\ \text{Hp.}/\rho A)}$$

For the ideal propeller the slipstream velocity can be simply computed from the thrust or from the horsepower provided the diameter of the propeller is known.

In analyzing propeller tests where both the horsepower and thrust are known the slipstream velocity is computed from the thrust and disk area of the propeller and the corresponding horsepower required for an ideal propeller is computed from the formula

$$\text{Hp.} = \rho A\frac{v^3}{4}/550$$

This ideal horsepower divided by the actual horsepower required by the propeller is a measure of the efficiency of the propeller as a static-thrust producer.

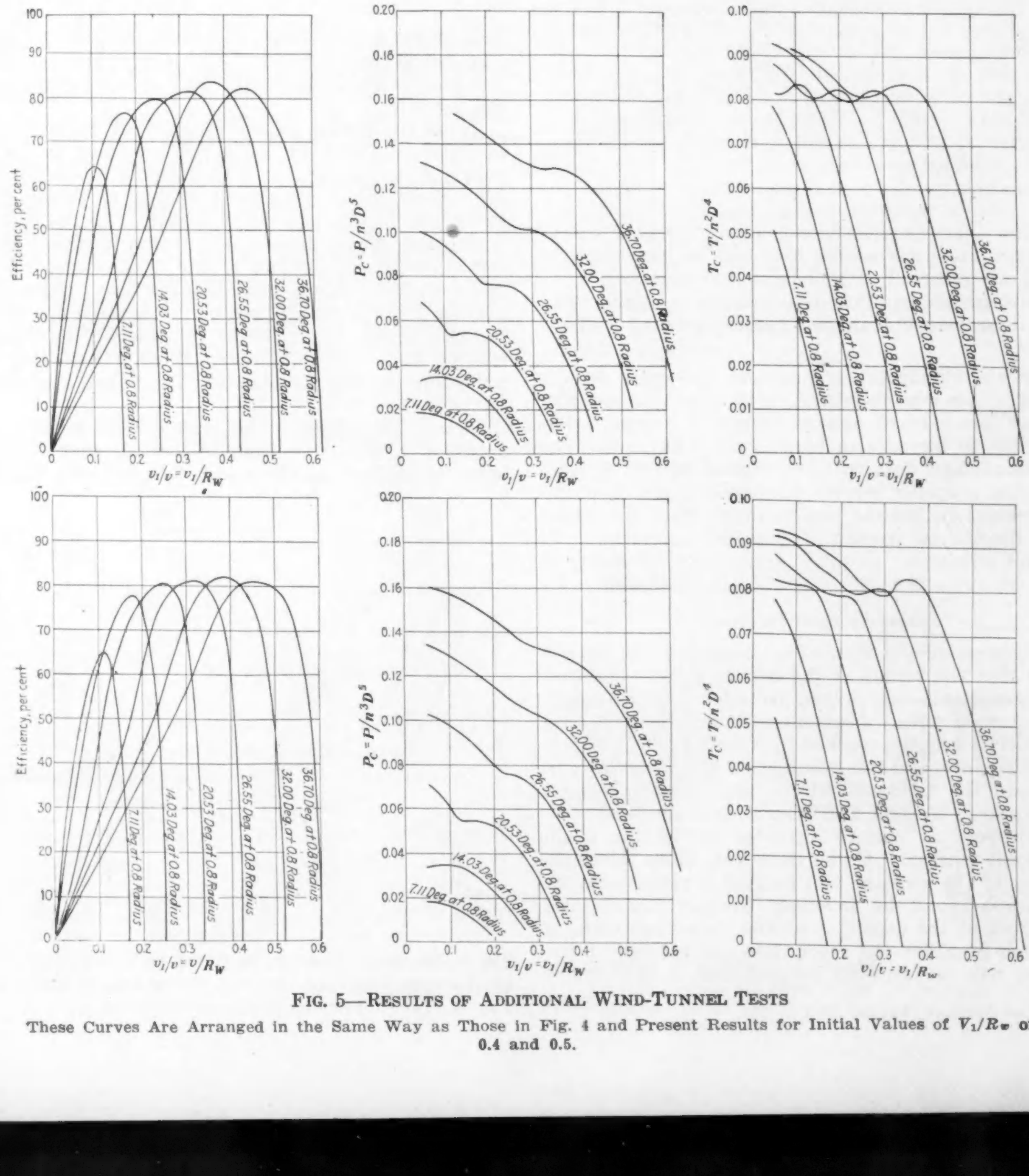

FIG. 5—RESULTS OF ADDITIONAL WIND-TUNNEL TESTS

These Curves Are Arranged in the Same Way as Those in Fig. 4 and Present Results for Initial Values of V_1/R_w of 0.4 and 0.5.

In Fig. 2 the efficiency of a typical metal propeller is shown at various angular-settings and at various tip-speeds. The dot and dash line indicates a tendency toward discontinuity which, in general, occurs at a higher velocity for the lower angular-settings. The lower angular-settings show progressively higher efficiency than the high angular-settings. At all settings the loss in efficiency is progressive as the tip speed is increased.

The net result of changing the pitch setting is indicated more clearly in Fig. 3 where, in the upper chart, the efficiency of the propeller is plotted against horsepower for the various pitch-settings. These data indicate a considerable net gain in efficiency at the lower pitch-settings. The lower chart shows the efficiency of the propeller as a static-thrust producer plotted against the static thrust.

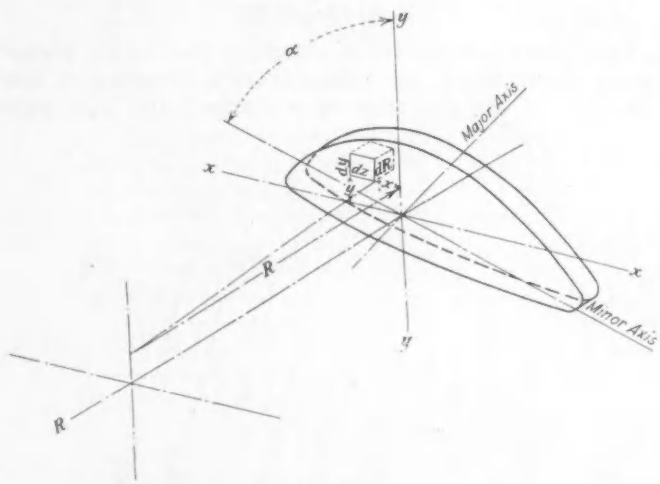

FIG. 6—CENTRIFUGAL FORCE ACTING ON A SMALL ELEMENTAL VOLUME OF A PROPELLER BLADE

From the standpoint of practical operation, we can gain by a lower pitch-setting, both in actual propeller efficiency for take-off and in increased engine horsepower due to increase in revolutions. Advantage can be taken of these data with the present type of ground-adjustable propeller where emergency take-off conditions require it, but the engine cannot then be opened to full throttle on account of excessive revolution. To take full advantage of pitch adjustment, it must, of course, be under the control of the pilot in flight.

Supercharged Engines

For convenience in discussing these engines we will assume that the torque of the engine is kept constant at various speeds and various densities. These conditions are never wholly encountered in practice, but they are rather closely approached in certain modern supercharged engines, and this assumption will aid greatly in visualizing the fundamentals of the problem without mathematics. We will also assume that the best indicated airspeed at various altitudes during the climb can be kept constant. Under these conditions the angle of attack of the airplane will be kept constant and the true airspeed will be inversely proportional to the square root of the density. At the same time using a fixed-pitch propeller the revolutions per minute of the propeller will be inversely proportional to the square

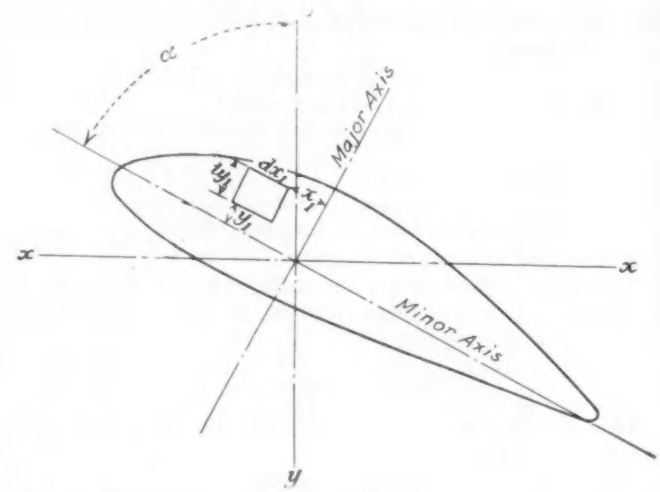

FIG. 7—CENTRIFUGAL FORCE ACTING ON A SMALL ELEMENTAL VOLUME OF A PROPELLER BLADE IN WHICH THE CENTER OF GRAVITY OF THE ELEMENT LIES ALONG A RADIAL LINE PERPENDICULAR TO THE AXIS OF ENGINE ROTATION

root of the density, and the power delivered by the engine being proportional to the revolutions per minute will be also inversely proportional to the square root of the density[3].

These conclusions follow very simply from the characteristic equation of the power absorbed by the propeller, $P = \rho P_c n^3 D^5$. In this formula P_c is dependent only on the ratio of forward velocity to peripheral velocity and is independent of density. In the case just mentioned, the airplane velocity being inversely proportional to the square root of the density and, the propeller revolutions per minute being also inversely proportional to the square root of the density, the ratio of forward speed to peripheral velocity will be constant, making P_c a constant during climb. Obviously these conditions satisfy the equation for power absorbed by the propeller.

Thus if the airplane flies from ground level to some height at which the density is one-half that at ground level, for example at about 19,000 ft. altitude, the speed

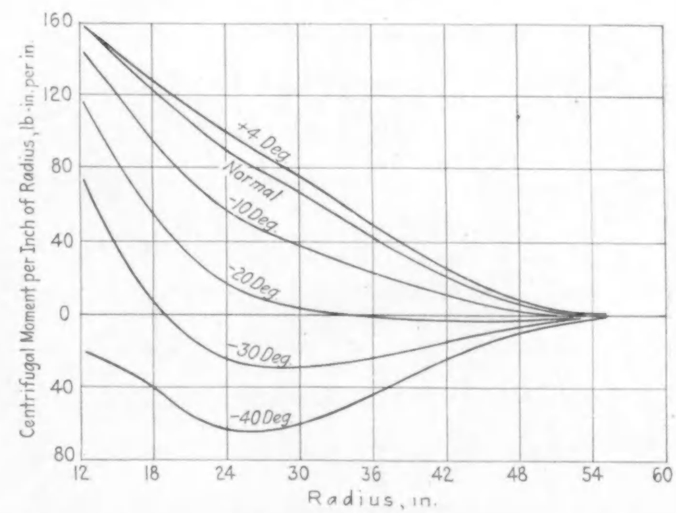

FIG. 8—TWISTING MOMENT PRODUCED BY CENTRIFUGAL FORCE AT VARIOUS PORTIONS OF THE PROPELLER BLADE AND AT VARIOUS ANGULAR-SETTINGS

[3] See THE JOURNAL, August, 1918, p. 132.

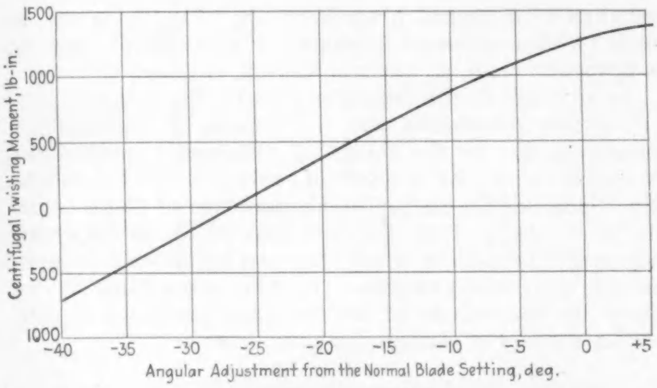

FIG. 9—TOTAL TWISTING-MOMENT PRODUCED BY CENTRIFUGAL FORCE ON A PROPELLER BLADE SET AT VARIOUS ANGLES

of the propeller will be about 1.4 times that at the ground. Or, putting this in another way, the number of revolutions per minute near the ground will be only about 70 per cent of that at 19,000 ft. If we assume the engine to turn at the maximum safe speed at the top speed of the airplane in level flight at 0.5 relative density and the number of revolutions per minute during the climb at 0.5 relative density to be substantially 90 per cent of that at top speed, then the number of revolutions per minute in the climb at ground level will be only 63 per cent of the maximum safe speed of the engine, so that a loss of about 37 per cent of the power available will have occurred.

This condition makes the adjustable-pitch propeller of primary importance in connection with the supercharged engine. In adjusting the pitch to meet the various conditions of flight, such as the climb, top speed, great altitude flying and the like, we must change the angles at all portions of the blade equally. Obviously this will change the system of angles of attack at the various stations since the angle of advance changes more rapidly at the portions near the hub than at the portions near the tip when the ratio v_1/v is changed. To know whether this change in the system of angle of attack will seriously reduce the efficiency when the propeller is operating at values of v_1/v other than the designed value is of interest.

Figs. 4 and 5 present the results of a series of wind-tunnel tests on model propellers of the same plan form as the Standard Steel Propeller Co. A Series of propellers. The tests indicate that changes in the system of angle of attack incident to adjustment of the pitch will not have a serious effect over the range of angle that is likely to be used in practice.

Forces Affecting Control-Adjustment Operation

In the adjustable-pitch propeller the ease of operation of the control adjustments is very important. The forces required to operate these controls result from three causes, which are given in their order of importance, (*a*) frictional forces, (*b*) twisting moments produced by centrifugal force and (*c*) twisting moments produced by air pressure.

The frictional forces are present principally in the thrust bearing that takes up the centrifugal force and the two bearings that absorb the thrust and torque reactions. The most satisfactory way to reduce these frictional moments to the minimum is by the application of suitable ball or roller bearings. This is a mechanical engineering problem and can be solved in a number of different ways very satisfactorily. In spite of the very great magnitude of the centrifugal force and the thrust and torque reaction, a good ball or roller bearing having a coefficient of roller friction of 0.1 per cent, or less, will reduce the operating friction to a comparatively small figure. Probably the effect of the engine pulsation even reduces the coefficient of rolling friction below the usual figure applicable to bearing practice.

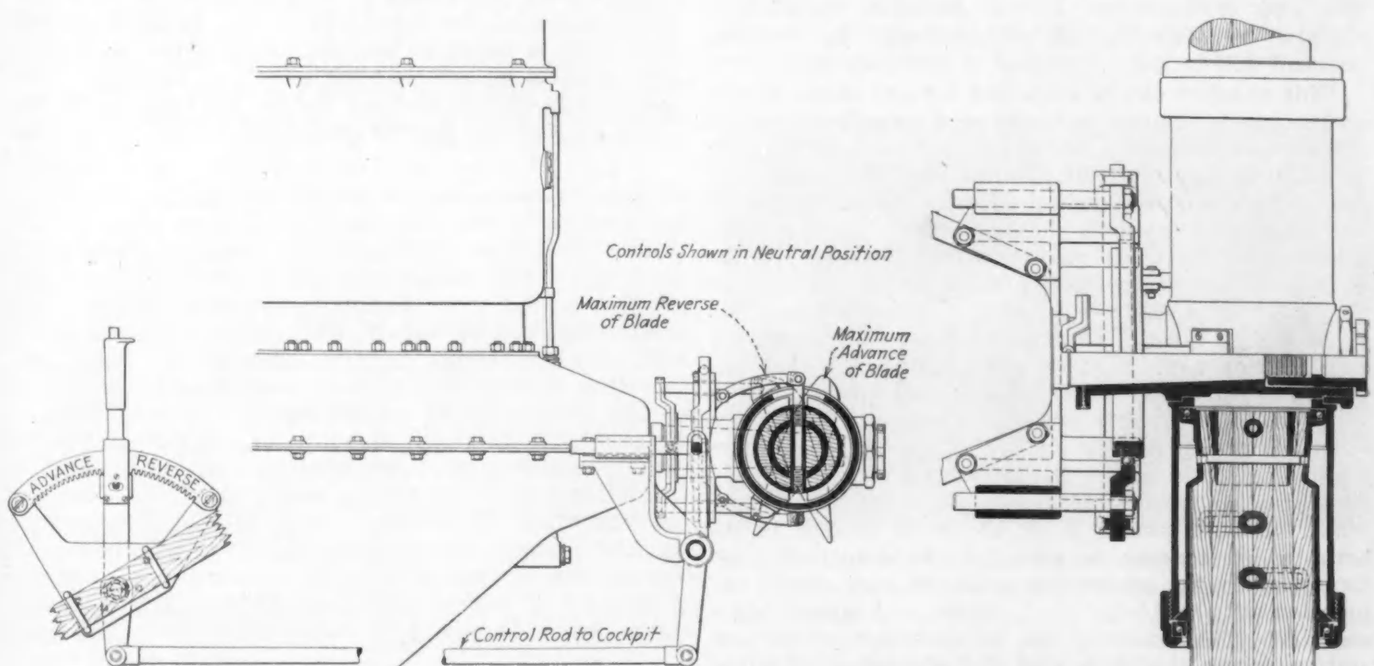

FIG. 10—HART REVERSIBLE PROPELLER APPLIED TO A JN4-H AIRPLANE
The View at the Left Shows the Control Mechanism in Neutral Position, and That at the Right Shows the Assembly of a Wooden Blade in the Propeller Hub.

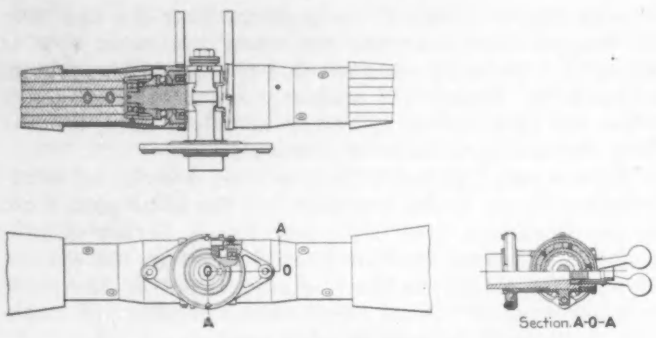

Fig. 11—An Adjustable-Pitch Propeller

This Type Has Wooden Blades and Was Developed for the 300-Hp. Wright Engine, by the Engineering Division of the Air Service at McCook Field

The twisting moment introduced by the centrifugal force, however, requires special treatment, and I shall give briefly the method used to neutralize these twisting moments.

In Fig. 6 we may consider the centrifugal force on a small elemental volume whose coordinates are R, x, y, and whose volume is $dx \cdot dy \cdot dR$. The weight of this volume will be $\delta\, dx \cdot dy \cdot dR$, if δ represents the density of the material. The centrifugal force on this element will have a component in the direction of the R axis which cannot cause twisting and a component in the direction of the x axis which has a moment arm y, about the reference axis of R.

The centrifugal force on any point is equal to $M\omega_2\sqrt{(R^2+x^2)}$ *since* (R^2+x^2) is the distance from the axis of revolution. The component in the x direction will then be $dM\omega^2x$, as is obvious from analysis of the vectors. The mass dM is equal to $\delta\, dx \cdot dy \cdot dR$. Hence the x component of the centrifugal force on the small element will be equal to $(\delta/g)\,\omega^2 \cdot x \cdot dx \cdot dy \cdot dR$ and the twisting moments of the elemental portion about the axis of reference R will be equal to $d^3QR = (\delta/g)\,\omega^2 \cdot x \cdot y \cdot dx \cdot dy \cdot dR$. Consequently the twisting moment will be $QR = (\delta/g)\,\omega^2 \cdot x \cdot y \cdot dx \cdot dy \cdot dR$.

This quantity can be evaluated for any shape of propeller, but is simplest in the type of propeller in which the centers of gravity of the various sections lie along a radial line perpendicular to the axis of engine rotation, this line corresponding with the axis about which the blade is rotated in changing pitch. In this case, shown in Fig. 7, we may transfer the axes to the principal axes of the section substituting for x value the value of $x_1 \sin\alpha - y_1 \cos\alpha$ and for y the value $x_1 \cos\alpha + y_1 \sin\alpha$. The expression for the centrifugal twisting moment will then be $QR = (\delta/g)\,\omega^2 \iiint (x_1 \sin\alpha - y_1 \cos\alpha), (x_1 \cos\alpha + y_1 \sin\alpha)\, dx_1\, dy_1\, dR = (\delta/g)\,\omega^2 \iiint [x_1^2 \sin\alpha \cos\alpha - y_1^2 \sin\alpha \cos\alpha - x_1y_1 (\sin^2\alpha - \cos^2\alpha)]\, dx_1\, dy_1\, dR$. $\iint x_1^2\, dx_1\, dy_1$ is the moment of inertia about the major axis, and $\iint y_1^2\, dx_1\, dy_1$ is the moment of inertia about the minor axis, while the third term $x_1\, y_1\, dx_1\, dy_1$ is the product of inertia which reduces to zero for the principal axes. Consequently the integration gives the very simple expression $QR = (\delta/g)\,\omega^2 \int (\text{I major} - \text{I minor}) \sin\alpha \cos\alpha\, dR$. This quantity can be evaluated at various stations along the blade and plotted against R, after which the integration can be carried out graphically. Fig. 8 shows the rate of twisting moment at various portions of the propeller blade and at various angular-settings of a typical propeller-blade. Fig. 9 shows the total twisting-moment produced by centrifugal force on a propeller blade at various angular-settings.

In addition to the centrifugal twisting-moments, certin twisting-moments are introduced by air-pressure reactions, due to the center of pressure usually being eccentric with the center of rotation of the blade. Knowledge of the nature and magnitude of these twisting moments is of the greatest importance in designing adjustable propellers, since they can be offset to a large extent by counterweights. At the same time if we know the magnitude of the twisting moments, it furnishes a basis of design for the controls.

Designs Developed

The principal obstacle in the way of a satisfactory adjustable-pitch propeller has been the difficulty of providing a construction with a sufficient factor of safety, together with a satisfactory method of control and light weight, as well as good aerodynamic features. Examples of some of the experimental models worked out under my direction are shown in the Figs. 10 to 13. The experiments have been carried out mainly with three types: (*a*) those having wooden blades (See Figs. 10 and 11), (*b*) those having metal blades (See Fig. 12) and (*c*) those having blades of bakelized canvas (See Fig. 13).

The metal propellers offer an attractive solution to the adustable-pitch propeller problem as they are easily attached to the metal hub. Fig. 12 shows a metal propeller built by the Standard Steel Propeller Co. of Pittsburgh, the mechanical construction being designed by Thomas A. Dicks.

Fig. 14 illustrates the control lever and the device for synchronizing the throttle opening with the propeller pitch. When the propeller is in the forward-pitch position and the throttle is open, as in the view at the left, a block drops behind the small pin on the control lever preventing it from going below the minimum safe-pitch for flying. When the throttle is cut-off this block is raised so that the propeller can be shifted into neutral or reverse-pitch position. When the propeller is in neutral position the pin lies underneath the block so that the throttle cannot be opened. After the

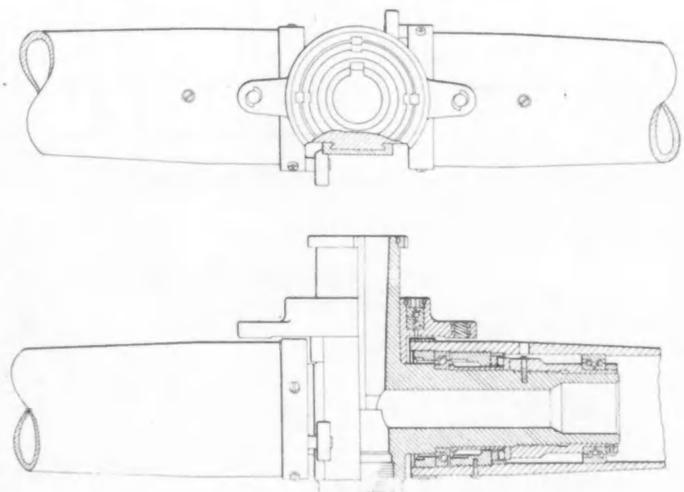

Fig. 12—A Reversible Steel Propeller

In This Design the Blades Are Easily Attached to the Metal Hub.

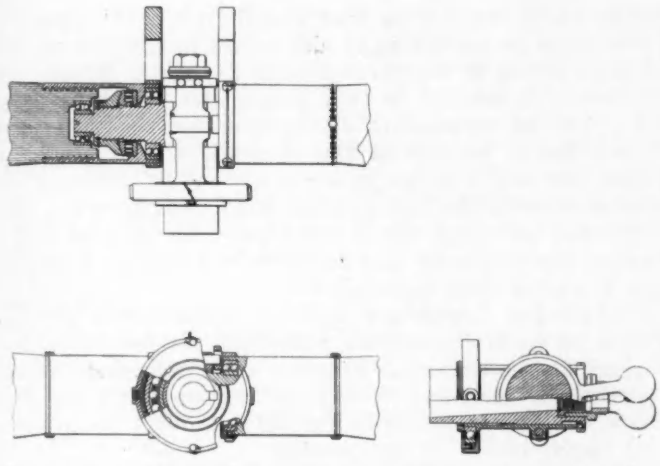

FIG. 13—A REPRESENTATIVE OF THE THIRD CLASS OF ADJUSTABLE-PITCH PROPELLERS

The Blades in this Propeller, Which Was Developed for the 180-Hp. Wright Engine, Are of Micarta Bakelite and Were Built by the Westinghouse Electric & Mfg. Co.

full reverse position is reached, as in the view at the right, a small hook permits the throttle to be thrown on or off by a slight motion of the pitch-control lever. For operating the reversible propeller in landing the action has to be very rapid if the propeller is to be truly effective as a brake. This type of propeller, being controlled by a simple lever, gives very satisfactory operation in this respect.

Static and Elastic-Stress Analyses

The stresses in the propeller blades are of considerable interest particularly when dealing with novel materials with which there has been very little experience in practice. The static-stress analysis is relatively simple, though in some cases it is rather tedious. To obtain a true understanding of the nature of the stresses in propellers, however, applying a method for an approximate elastic analysis is necessary. I might safely say that a complete elastic analysis of a propeller would be impossible with the limited knowledge of the elastic stresses even in bodies of a simple form.

I have found the following method of stress analysis to be useful in studying these propellers. The first step in the analysis is to find the direct centrifugal stress. If δ is the density of the material the centrifugal force on a small elemental strip of the propeller will be $(\delta A/g)\omega^2 RdR$. This quantity can be integrated from the tip to any station under consideration to find the total centrifugal force on that station. The unit centrifugal-stress in direct tension on the station will be the total centrifugal force on the station divided by the area of the cross-section at that station. If the sections of the propeller are spaced along a radial line perpendicular to the axis of rotation no static bending-moments due to centrifugal force are present. For any other arrangement or propeller shape, the bending moment produced by the centrifugal force of any station on any other station must be computed in the thrust and torque planes.

The next step necessary is to construct thrust and torque grading-curves for the propeller. These can be computed with sufficient accuracy by the simple airfoil method without corrections for inflow, an over-all empirical factor being applied to all the stations. From these thrust and torque grading-curves the bending-moment grading-curves in the thrust and torque planes can be worked out, and these curves integrated to give the total bending-moment on various stations due to thrust and to torque. After having found the bending moments, the total bending-moments in thrust and torque planes may be added vectorially to give the resulting bending-moment and its axis.

To find the most highly stressed fiber the neutral-axis method can be applied. This method is described in many textbooks on mechanics, the tangent of the angle between the minor axis and the neutral axis being equal to the product of the tangent of the angle between the resultant moment axis and the minor axis multiplied by the ratio of I-minor divided by I-major. This method of the neutral axis will give the location of the most highly strained fibers and their stress. To get the total resultant stress at these points, we add the direct centrifugal tensile stress to the bending stress on those fibers that are put in tension as the result of bending, and subtract the direct centrifugal tensile stress from the bending stress on those fibers that are put in compression.

To make an approximation of the elastic stress, we must first estimate what the deflection would be if no restoring moment due to the centrifugal force were present. To approximate this deflection we can assume that the minor axes of all the sections lie in the same plane and that the resultant air pressure is in a plane normal to the plane of minor axes. This is, of course, a very rough approximation but serves to give an idea of the magnitude of the deflection to be expected.

If E represents the modulus of elasticity of the material, I the moment of inertia at any station about the minor axis and M the bending moment on the station, M/EI will represent the curvature at the station under consideration. We can now plot a curve of M/EI for the various stations against radius. Since both the slope and deflection at the hub portion of the blade are zero, we can integrate this curve from the hub out to

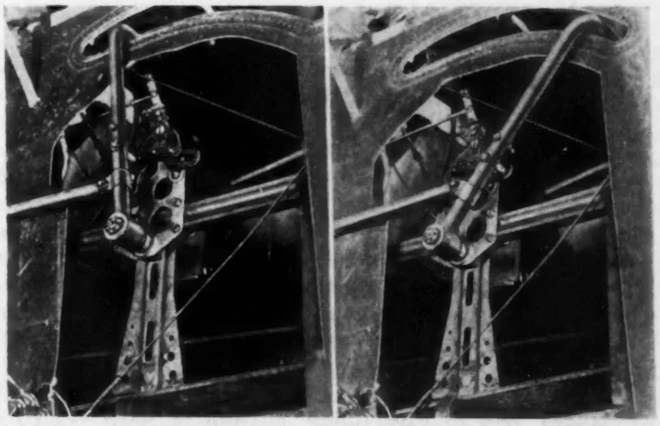

FIG. 14—TWO VIEWS OF THE DEVICE FOR SYNCHRONIZING THE THROTTLE OPENING WITH THE PROPELLER PITCH

In the View at the Left the Propeller Is in the Forward Position with the Throttle On, and the Pitch Cannot Be Reduced beyond the Minimum Safe-Value for Flying Due to a Block Having Dropped behind a Pin on the Pitch-Control Lever. When the Propeller Is in the Extreme Reverse Position, as in the View at the Right, the Pin Has Engaged a Small Hook at the Right, Thus Permitting the Throttle To Be Cut in an Emergency by a Slight Movement of the Pitch-Control Lever.

the various stations and find the slope. This can again be plotted and a second integration carried out to find the deflection at the various stations.

Comparing this deflection with that which would be necessary to have the bending moments due to centrifugal force just balance those due to the air-pressure reactions will be of interest. To have the centrifugal bending-moments neutralize those due to air-pressure reactions, the ratio of centrifugal force per unit of length to air pressure per unit of length at any station must represent the slope of the line of centroids of the cross-sections at that station. We can therefore plot this ratio against the radius and carry out the integration from the center to various stations and plot a new curve with corresponding deflections. By taking the mean ratio of the deflection necessary to balance the air pressure by centrifugal force to the deflection that would occur if no centrifugal force were present, we obtain an approximate idea of the magnitude of the elastic stress in comparison with the static stress. Of course this method is very rough, but it serves very well for the purposes of comparison and really gives a much better picture of the strength of the propeller than the static-stress analysis alone. In addition to these stresses that are readily calculated, however, the propeller is subjected to vibratory stresses of very great importance so that the present methods of analysis are sometimes inadequate.

In closing, I may say that the aerodynamic advantages of controllable-pitch propellers are becoming increasingly important as propeller-tip speeds and engine horsepower increase. With improved materials and design, we should soon be in a position to meet the practical requirements of the problem.

THE DISCUSSION

CHAIRMAN LESLIE MACDILL[4]:—I want to thank Mr. Caldwell on behalf of all those present for the very interesting paper he has presented. I feel that all of us appreciate the increasing necessity for the development of the controllable-pitch propeller to the stage where we can put it into production. This is accentuated by the development of the supercharged engine, which I think we can now regard as an accomplished fact.

LIEUT-COMMANDER CLINTON H. HAVILL, U. S. N.[5]:—I think the subject has been rather well covered, but no great stress has been laid upon the quantitative value of this blade angle that we have to change. In my opinion we might have several different ranges. We might have a controllable-pitch propeller the angle of which we could change 360 deg., which would not be of much use. We might have a range of from 12 deg. astern to 40 deg. ahead. That type of propeller would be completely reversible. Or we might have a range of between 5 and 10 deg. in the ahead position.

As I see the problem, we want a propeller that has a range in the head position of 5 or possibly 10 deg. at the outside. I think that confining our efforts in those directions would be well; then we could leave out the completely reversible type. In the future the problem probably will work out so that some type of automatic pitch-control will be made which will give from 3 to 5 deg. in the head position and a completely reversible propeller for handling in a small stream the large flying-boats which are very hard to handle in high winds. That is the only field that I can see for a completely reversible propeller at present. Brakes have practically solved the problem of stopping without all the ground-looping troubles.

The Navy has on order five automatically controlled propellers, one to give 3-deg. change in head position from take-off to top speed and three others to give a 5-deg. change automatically, depending on the combination of air and engine speeds. These are in the experimental stage as yet and I do not know how they work out.

CHAIRMAN MACDILL:—I was rather interested in hearing these papers read from the standpoint of when it is necessary, due to the increasing power of the engine to go to a power control rather than a hand control.

LIEUT-COMMANDER HAVILL:—I think power control will be the one, but I think the automatic control will be the final answer.

Efficient Range of Automatic Control

CHAIRMAN MACDILL:—How far do you think you could go on horsepower, Mr. Caldwell, in the matter of control?

FRANK W. CALDWELL:—I do not exactly know, but I think we must have some limit in the matter of the manual control. My thought would be that probably we shall develop away from the manual control, not of necessity, but because we can get a simpler device in some other way.

CHAIRMAN MACDILL:—What is the range on the automatic control as far as efficiency is concerned, Commander Havill?

LIEUT-COMMANDER HAVILL:—Three of them are for the Wasp and the others for the Hornet engine.

CHAIRMAN MACDILL:—Do they give complete control from the take-off?

LIEUT-COMMANDER HAVILL:—The Hornet engine job, at rest on the ground, has the propellers set at approximately 18 deg. When the propeller attains a speed of about 900 r.p.m., the angle drops to 15 deg. until an air speed of about 100 m.p.h. is reached. Then the angle will increase automatically to 18 deg. and stay there for the free-flight setting and will give the take-off for the large flying-boats. That is probably a crude form of automatic propeller but I think eventually we can get that to work. It weighs only 8 lb. more than the standard hub. I think that will be one of the coming developments.

CHAIRMAN MACDILL:—I think that perhaps some of us here would be rather interested in having a further description of that automatic control.

Navy Automatic-Control Hub

LIEUT-COMMANDER HAVILL:—I can describe it to you. We worked out a novel bearing that eliminated all the ball-bearings and made the control fairly free. It has a specially designed blade, and the efficiency curve

[4] Air Service, McCook Field, Dayton, Ohio.
[5] Bureau of Aeronautics, Navy Department, City of Washington.

shows no sharp peaks. In other words, we have a blade with flat characteristic due to proper pitch-distribution and a standard blade-root. The blade is attached to approximately 840 piano wires in the hub. These wires have a tensile strength of 300,000 lb. per sq. in., giving a total breaking load that is approximately equal to the full strength of the blade root. The wires are wound in two sets with slightly different angles so that at a low centrifugal force the blade tends to turn in one direction and at a high centrifugal force to turn in the opposite direction, the change of direction occurring at some predetermined speed. The friction of a ball-bearing is eliminated and the centrifugal force acting on the blades themselves, together with the movement of a plunger that has a cam slot on it that moves in or out, depending on the centrifugal force, governs the desired angle.

This construction permits of two possible angles, one for take-off and the other for top speed or for cruising, as desired. Getting a smooth curve of angle for all possible conditions is not possible with centrifugal force alone, yet the two points such as the take-off angle and the cruising angle can be obtained. This idea is merely an experimental step in the direction of automatically controlled variable-pitch.

However, we are receiving some complaints from the engine builders. We found that we could cruise along with the Hart propeller, which we bought for the J-5 engine, at very close to 9/10 of the maximum speed at about 1100 r.p.m. of the propeller. The bearing pressures in the engine go up and other troubles developed due to high horsepower at a low number of revolutions.

The engine is fairly good at a certain number of revolutions per minute per horsepower, but when it is kept at almost a constant horsepower until it is slowed down and the throttle is full, the life of the engine comes down. At least that is what the engine builders say. The reason for limiting the change to 5 deg. was that when we went much more than that we experienced bearing trouble during cruising at a low number of revolutions per minute and a high horsepower.

Wing Theory Applied to Propeller Blades

MAX M. MUNK[6]:—I feel that in the past years not enough has been done in the way of research on and development of propellers. The propeller has really been somewhat neglected and the few men who have devoted their efforts to this phase of research therefore deserve particular praise.

I notice in Fig. 1 of the paper that the coefficient of lift has been denoted by K_y, although Mr. Caldwell referred to it as the "lift coefficient". This latter is standardized in this Country and is generally noted by C_l. Looking at the curves of Fig. 1, I would think that K_y is a coefficient different from our usual lift coefficient and only half of it. Clarity on this point is important for the understanding of Fig. 1 and the entire paper.

MR. CALDWELL:—K_y is indeed the old-style coefficient, half of the usual lift coefficient.

MR. MUNK:—To obtain C_l we have therefore to multiply the values of Fig. 1 by 2, and if we do so we obtain about 1.1 for the maximum lift-coefficient of the propeller blades, that is practically the same as with the ordinary airfoils. This brings me to the main point that I desire to raise, which is the question whether we are justified in using ordinary airfoil tests in wind-tunnels for studying questions referring to propeller blades. I understand that the curves in Fig. 1 are obtained from such plain wind-tunnel model-tests.

MR. CALDWELL:—Yes, indeed, they were obtained from airfoil tests with very small models.

MR. MUNK:—Finding myself in the company of a great number of propeller experts, I should like to use the opportunity to divulge experiments that are comparatively new and have not yet been published and that have a direct bearing on the point I raised. I came to these as a result of the special way I understand the propeller action. Most propeller investigators like to discuss the propeller as a whole. A propeller has about four or five variables giving an infinity of relations, and this makes a clear insight very difficult. These men, of course, have had many years of mental training with propeller characteristics and are fully familiar with the many sides of the problem. The ordinary engineer, however, for whom the propeller is only a small fraction of his work, is not so familiar with the many variables and often has difficulty in readily grasping what the propeller experts mean. Their thoughts do not become entirely clear to him and this makes the discussion tedious. To overcome this difficulty, I have always tried to discuss a propeller as a plurality of small wings moving in a circular path and to apply to these wings the ordinary wing theory, forgetting about the propeller as a whole.

Following this line of thought, I found several years ago that the lift coefficient plotted against the angle of attack of such little airfoils moving in a circle, as do the propeller-blade elements, does not give the same curve as ordinary airfoils in wind-tunnels. The slope of the lift curve is different in both cases. The difference is not just a few per cent, enough to furnish an opportunity to talk about in a meeting like this, but the discrepancy is really large, amounting to about 40 per cent. That means that an airfoil which serves as a part of the propeller blade has sometimes almost 1½ times as much lift at the same angle of attack as it would have when serving as an ordinary airfoil element. This suggests that something is fundamentally different in those cases and it seems doubtful whether we are really allowed to use an ordinary wing-model test in research work applying to propellers. Since we positively found out that a 40 to 50-per cent discrepancy exists in the lift of these two differently applied airfoils, large discrepancies possibly also exist in the other characteristics, such as drag, for instance.

Attempt To Check Propeller Air-Velocities

About a year ago, in an attempt to obtain more light about this, these questions came up, and Dr. A. F. Zahm was kind enough to conduct some tests for me in the wind-tunnels at the Washington Navy Yard. We were limited to a small number of tests and the results did not give a definite answer to the question. However, they brought us a good step forward and I laid them down in a paper that has not yet been published. The broad idea that I tried to explain in this paper is the following: If we have an ordinary airfoil, for instance, in a wind-tunnel, but the same thing would hold for an airplane wing, we have practically a uniform air-flow in front of the airfoil. This is a necessary condition for certain well-known relations between the lift coefficient and other variables. Compare with this

[6] Alexander Industries, Inc., Colorado Springs, Colo.

the flow in front of a blade element of a propeller blade.

Short examination shows that the velocity on top of the blade section, if I may use the word "top", is really different from the velocity at the bottom. We know that the propeller leaves behind it a slipstream that not only has a velocity parallel to the axis but also a rotating velocity at right angles to it. The latter is created by the blade element while passing through the air and in consequence the air that has already passed the blade has a different velocity from the air that has not yet passed. The blade element is, therefore, situated in the air-flow with variable velocity. This might be the explanation for the discrepancy alluded to before. If we could imitate this variable velocity wind-distribution in a wind-tunnel, we might obtain wind-tunnel results different from the results obtained in ordinary wind-tunnels and more useful for our purpose.

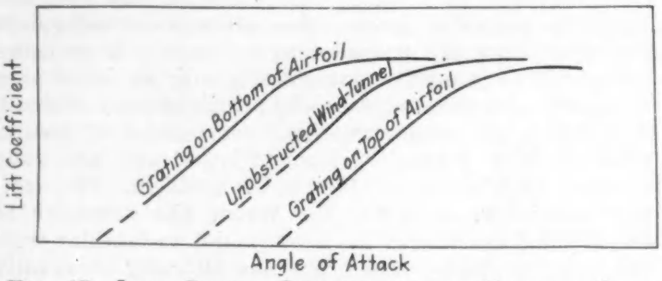

FIG. 15—LIFT CURVES OBTAINED UNDER VARYING CONDITIONS IN A WIND-TUNNEL

Following up this trend of thought and being unable to provide a wind-tunnel with a continuously varying velocity, I suggested the following arrangement of tests: Half the cross-section of the wind-tunnel was obstructed by a grating composed of equally spaced round rods; the other half of the wind-tunnel cross-section remained unobstructed. These rods were parallel to the span of the airfoil, and in one test they were on top of the airfoil, and on the bottom in another. In both cases we obtained lift curves showing virtually the same slope of the lift against the angle of attack. However, we got the lift at entirely different angles of attack. Fig. 15 illustrates this point. At the right I have plotted the angle of attack and at the top the lift coefficients obtained in the unobstructed wind-tunnel and in the wind-tunnel obstructed by grating on the top and on the bottom of the airfoil. The results suggest that we are on the right track and I wish those engaged in propeller research would follow this line of attack. Until that has been done we should be careful in applying ordinary wind-tunnel tests to propeller research. Later, we may learn how to arrange the air-flow in special wind-tunnels for propeller research.

These arguments are, of course, important in connection with every propeller, whether the pitch be variable or not. I believe, moreover, that as soon as we attempt variable-pitch propellers the need to study these questions to arrive at the best propellers will be even greater. In either case the most important question of propeller design is still the same as it always was: which lift coefficient to use and which drag coefficient to assume in connection with the lift coefficient. I do not know as yet what is the best lift-coefficient to use in propeller design and I have been unable to find it in the literature. If our special propeller experts would get together and find a solution of this question, they would render a very important service.

The tests illustrated in Fig. 3, referring to a propeller the blades of which were turned, show that this mere turn did not change the propeller efficiency very much. This strengthens my opinion that, broadly speaking, the drag coefficient within a certain range of the lift coefficient of propeller-blade sections does not change very much and we have chiefly to learn about the limit of this range of small drag-coefficient.

Gearing of Aircraft Propellers

By T. P. Wright[1] and R. E. Johnson[2]

Cleveland Aeronautic Meeting Paper — *Illustrated with* Photographs and Chart

FOLLOWING a brief outline of the development of aircraft propellers and a statement of the most important fundamentals of propeller design, the authors discuss the problem of propellers for use on geared-down engines, this being the installation of reduction gearing between the crankshaft of the engine and the propeller hub when the increase of airplane-performance characteristics more than offsets the added complication of the installation. The advantages and the disadvantages of using reduction gearing are considered.

Concerning the installation of reduction gears, the authors state that the decision whether to use gears or not must result from a compromise between the gains and the losses involved and the amount of net gain depends largely upon the particular engine and airplane combination and its designed performance. It is said also that gearing is a design refinement and that, very often, a similar gain in performance can be obtained by using more care in attaining cleanness of the general design-characteristics of a given airplane. The authors believe that the trend in large multi-engine transport-airplanes will be decidedly favorable to the use of gearing.

THIS practice of gearing aircraft propellers was first adopted extensively in 1916. Under certain conditions, the installation of some type of gearing between the powerplant and the propeller led to an improvement of the general performance of a given airplane; on the contrary, apparently similar installations resulted in little or no improvement. This raised the question of when it is advantageous to add the extra complications of gearing to obtain increased performance.

The Wright Brothers used two-blade wooden-propellers on their first flights. Bleriot used heavy, cumbersome and inefficient built-up metal propellers, but they opened possibilities for the later development. The majority of the following pioneers were partial to wooden propellers of various shapes because of their comparative lightness and low cost, but experiments were continually being made with other materials. The development of the Leitner-Watts type in 1917 was one of the first outstanding variations from common practice; it was entirely of steel and had a separate hub. Later, the Micarta propeller was constructed of a composite material. It was not until 1921 that the present duralumin propeller was developed by S. Albert Reed.

During the war, four-blade propellers were developed for engines of large horsepower, because the power could be absorbed with a much smaller diameter than is required by a two-blade type. This was found to give a decrease in efficiency of from 4 to 6 per cent. The three-blade propeller is a compromise between the two other types; more power is absorbed per unit of diameter and at the same time the efficiency loss is less than with the four-blade propeller. Hence, today we find two, three and four-blade propellers of various materials and shapes. The metal propeller has become the standard equipment on practically all airplanes powered by 200-hp. or larger engines, because of the increased efficiency and longer life of this type of construction. The United States is probably more favorable to the metal propeller because of greater facilities and experience applicable to its construction. The wooden propeller still has the advantage, however, so far as weight is concerned, for diameters up to approximately 12 ft.; above this the added strength of the metal allows lighter construction.

The first installations of geared propellers gave questionable improvement in performance for the added complications of construction. Originally, the addition of gears between the power unit and the propeller was made with a somewhat different purpose than is found today. It was used on lighter-than-air craft, as an aid to maneuvering these large cumbersome types. Later came a trend to make a like installation on heavier-than-air craft for improvement of the performance characteristics in take-off and climb of the airplane, when the ordinary propeller is most heavily loaded. Today the problem is more involved and largely dependent upon the specific engine and airplane combination to which the gearing is to be adapted. The object of the use of gearing now is to obtain the most efficient power-absorption with the least amount of added complication.

Aircraft-Propeller Fundamentals

The propeller is one of the fundamental elements of all conventional aircraft and is the means whereby the power of the engine is transformed into thrust whereby the resistance to the translational motion of the airplane is overcome. It is similar in principle to the marine propeller which screws its way through the supporting medium. The thrust produced by the propeller is equal to the product of mass of air handled per unit of time by the velocity imparted to this mass of air. The propeller efficiency is the ratio of thrust horsepower to impressed horsepower, and it would be 100 per cent if the propeller operated like a frictionless screw on a nut, with no slip. The pitch of the propeller is similar to the pitch of a screw, and the actual pitch is always somewhat less than the theoretical because of propeller slip. The loads on the propeller and hub are threefold: direct bending, coming from the thrust in the blades and gyroscopic forces; torsion, due to the load distribu-

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tion across the chord of the propeller section; and direct stress, on account of the centrifugal forces caused by the blade rotation.

To give an idea of the magnitude of these forces on a typical metal propeller, let us assume a propeller having a diameter of 10 ft. turning at 1800 r.p.m. and absorbing 400 hp. installed in an airplane having a speed of 145 m.p.h. This will have a direct stress of 3800 lb. per sq. in. and a bending stress of 7500 lb. per sq. in. at a section 12 in. out from the axis of rotation. The torsional stress is small and is not considered in propeller calculations.

Limiting Factors in Propeller Design

Several limitations of design and construction, understood by the propeller designer, must be given careful consideration when studying the problem of gearing. From a manufacturing viewpoint, the equipment limits the propeller size that can be built. Although blades have been made up to a maximum disc-diameter of 20 ft., and available equipment allows construction up to a disc-diameter of 24 ft., the limitations of the equipment available make it inadvisable to go beyond this diameter. At present, the manufacturer is limited by the materials of construction he can use, those available being wood, steel, micarta and aluminum alloys. Efficient output of thrust horsepower limits the number of blades that can be used to two, three or four. Structural analysis determines the blade thickness and hub design to a large extent, and the airplane designer imposes certain fixed limits that must be met by the propeller design for a given craft.

In his layout of a new machine, the airplane designer often gives little thought to his propeller requirements until he has the design well advanced, which is a very poor method for securing efficient performance and presents to the propeller designer a very definite and difficult problem because he must furnish a propeller that will absorb a given horsepower at a given rate of revolution. It must not exceed a definite diameter which is determined by the airplane design from the viewpoint of ground or structural clearance. The propeller must operate efficiently within the range of velocity of the airplane, and its weight must not be excessive. These are the five basic factors of propeller design; and when one considers the great range of variation of each one, he can appreciate the problems of a propeller designer. Engine horsepowers vary from 30 to 1200 and more; diameters, from 5 to 20 ft.; the rated speed of engines, from 1400 to 3000 r.p.m.; weights, from 25 to 400 lb.; and airplane speeds from 70 to more than 300 m.p.h.

In addition, there are several important aerodynamic considerations. First, experience, coupled with research, shows that certain phenomena occur when the tip speed of the propeller approaches the velocity of sound. The result is a serious loss in efficiency at these high speeds for ordinary blades, but tests by S. Albert Reed, and more recently by the Aeronautical Research Committee of Great Britain and the National Advisory Committee for Aeronautics in the United States, indicate that this loss can be modified as a function of the blade thickness within certain limits. Apparently then, the occurrence of the phenomena can be postponed by using very thin tip-sections.

To date, the actual effect of the blade thickness is not determined quantitatively because practically all research we have mentioned has been conducted on comparatively thick sections on account of structural limitations. The phenomena were originally explained as being due to the compressibility of the air at the high velocity of the blade tip, but this theory is likely to be modified or completely changed in the near future. The present trend of the theory involves a cavitation of the air in the vicinity of the propeller tip which is similar from a theoretical viewpoint to the phenomena noted in the study of high-speed trajectories. Here, too, trajectories having velocities approximating that of sound show a notable change of flow conditions.

As a result of the research on propellers at high tip-speeds, it has become common practice to limit the rate of rotation so as to give a tip velocity not exceeding 1000 ft. per sec. for conventional types. Special design-conditions have been used which allow much higher rates of rotation, but only in connection with racing airplanes having high-powered engines and little is actually known of the efficiency obtained.

The second aerodynamic limitation of propeller design is the ratio v/ND, where D is the diameter of the propeller, N equals the rate of rotation of the propeller and v equals the translational velocity of the airplane. This ratio has been experimentally proved to be a function of propulsive efficiency regardless of the type of blade. The maximum propeller efficiency varies with the ratio v/ND for average metal propellers as shown approximately in Table 1, the figures being taken from a recent

TABLE 1—VARIATION OF METAL-PROPELLER EFFICIENCY

v/ND	Efficiency, Per Cent
0.30	65
0.40	70
0.45	74
0.50	76
0.60	80
0.70	83
1.00	86

propeller report by Fred Weick for the National Advisory Committee for Aeronautics[8]. The efficiencies of wooden propellers are about 5 per cent less throughout the range of v/ND than those given in Table 1. Other factors affect the efficiency of the propulsive unit but these deal more specifically with the cleanness of a given airplane design, particularly the cowl lines directly behind the propeller. This matter is a consideration worthy of discussion in itself, however, and no more mention will be made of it here, except to note that in general the relative loss of efficiency caused by interference behind the propeller will be less for propellers of large diameter, such as can be used with geared-down engines.

Propellers for Use on Geared-Down Engines

The background of propeller design gives a better understanding of the problem of propellers for use on geared-down engines, what it involves and its limitations. The problem is to install some sort of reduction gearing between the crankshaft of the engine and the propeller hub when the increase of airplane-performance characteristics more than offsets the added complication of the installation. This necessarily entails several disadvantages, but care in design of the various features usually will result in a net gain. The problem

[8] See National Advisory Committee for Aeronautics Report No. 306.

reduces then to a study of the advantages and disadvantages involved by a proposed installation of gearing and thus it becomes a problem typical to all types of engineering.

Regarding the advantages of a gearing installation, the greatest is the improvement of propulsive efficiency resulting from an increased value of the ratio v/ND. A change from an ungeared to a geared propeller on a given airplane involves a 2 to 4-per cent increase of v, a 30 to 40-per cent increase of D and a 50 to 100-per cent decrease of N, with the net result that the ratio v/ND increases from 10 to 50 per cent under favorable conditions. This represents a change of propeller efficiency of 5 to 10 per cent, depending upon the range of v/ND values involved, as can be seen from Table 1.

To illustrate just what the foregoing means, consider an actual case of engines of different characteristics on the same airplane. A recent two-place observation-airplane built for the Army Air Corps used a Liberty engine that was designed to deliver 425 hp. at 1800 r.p.m. Later it was desired to place a new type of engine in the same airplane to replace the Liberty engine. This new engine was designed to deliver 435 hp. at 2300 r.p.m. The higher rated-number of revolutions per minute of the more recent engine allowed the same horsepower to be delivered for much less weight per horsepower, a factor so important in the design of all heavier-than-air craft. The comparative weights of the two are 852 and 684 lb.

The new engine was installed in the same observation class of airplane, everything else affecting speed remaining constant, and the Liberty installation was the faster of the two by a marked degree for straight level flight. From official test-data on the two airplanes, the speed was decreased by 3 per cent with each propeller absorbing the same horsepower. Both airplanes had direct drive, but they serve to illustrate the effect of the ratio v/ND upon propeller efficiency, for the 3 per cent is due to change of propeller efficiency only. In fact, from the viewpoint of cleanness of design, the Liberty was inferior. The value of v/ND for the Liberty installation was 0.745 and for the other installation was 0.608. The efficiencies corresponding to these values

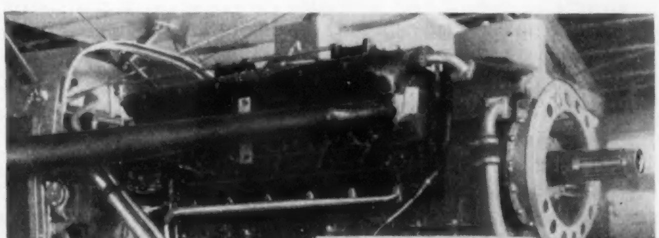


FIG. 1—GEARED CONQUEROR ENGINE MOUNTED IN A FALCON MAIL AIRPLANE

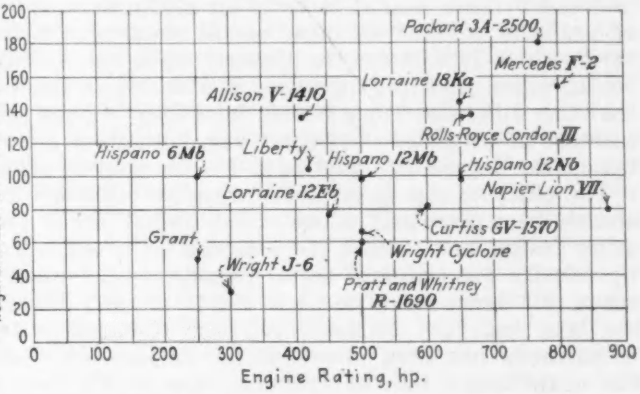


FIG. 2—WEIGHT INCREASE VERSUS RATED HORSEPOWER FOR TYPICAL GEARED AIRCRAFT ENGINES

are 84 and 80 per cent respectively and these figures approximately check the actual 3-per cent velocity-increase when the velocities are calculated using the two efficiencies. The installation of a 5 to 7 gear-reduction on the latter of these two engines would more than correct the speed loss, but other considerations make such an installation unwarranted. Many other examples could be cited where the ratio v/ND has been an important factor in the efficient performance of a given plane.

A second advantage of reduction gearing is the improved efficiency resulting from a smaller value of the ratio between the fuselage and the propeller-disc diameters. The slower-turning geared-propeller requires a larger diameter to absorb a given horsepower than does the direct-drive propeller; that is, as the propeller is geared down, its diameter increases so that the ratio of the body diameter to the propeller diameter decreases. It is easily understandable how this increases the efficiency. The body behind the propeller disturbs the air flow and thus cuts down the efficiency, and the less the relative body diameter is, the less is the relative disturbance; hence, the efficiency loss is less. This point is of great importance for high-speed aircraft because, unless gearing is introduced, the designed diameter of the propeller decreases as the designed speed increases and would thus increase the so-called body-coefficient.

Actual experimental data on the effect of the body-efficiency losses are insufficient to cite any specific figures, but much research on this subject has been conducted by the National Advisory Committee for Aeronautics, the results being in general agreement with those given here. In many cases, it has been impossible to account completely for the well-known increase of performance obtained by gearing the propeller without taking this body-coefficient effect into account. In the example cited, the actual increase of the speed of the Liberty observation airplane over that of the other airplane can be divided into two parts: a 2-per cent speed-increase because of the improved ratio v/ND, and 1 per cent because of the improved ratio between the fuselage and the propeller-disc diameters. This factor is realized when a geared engine is installed in a wing nacelle. For example, in the Curtiss Condor, a night bomber recently delivered to the Army Air Corps, two geared Conquerer engines that deliver 1250 hp. are used. The ratio v/ND for this plane is 0.74, which gives an efficiency for the three-blade propeller of 81 per cent. The actual efficiency must be higher than this because of the known resistance coefficient of the plane. The only explanation

of the difference is that there is an additional increase of propeller efficiency because of the small nacelle-disc ratio, which is 0.09 for the Condor, while the average for 10 other ungeared airplanes is 0.22. It is believed that this difference is equivalent to at least a 2-per cent increase of propeller efficiency. Fig. 1 shows a geared Conquerer engine mounted in a Falcon mail airplane.

The effect of tip speed upon propeller efficiency has already been discussed as one of the limitations of propeller design, and 1000 ft. per sec. was set as a limiting tip-velocity for ordinary metal propellers; for wooden types, this figure would be about 850 ft. per sec. During the last year, the National Advisory Committee for Aeronautics has been investigating, at Langley Field, the quantitative loss of efficiency due to tip speeds higher than the limiting value given here, and although its tests have not been conclusive in regard to thin blade-sections, they indicate that the loss is sufficient to warrant such a limit. Because of the lack of more conclusive tests in this regard, this limit of a tip speed not exceeding 1000 ft. per sec. will be used to cover the general-service type propellers; however, it should be remembered that special design may allow higher values to be used without serious results, but this is outside the scope of this paper.

The tip speed is a simple function of the diameter and the rate of rotation of the propeller and, for a given number of revolutions per minute, there is a diameter that will give the limiting tip-speed of 1000 ft. per sec. Table 2 gives the limiting diameters that can be used for various rates of rotation from the viewpoint of tip speed and efficiency.

Table 2 shows that for present-day engines with the high crankshaft-speeds, the diameter of propeller allowed on an ungeared engine is very small and it is doubtful if the power could be absorbed efficiently by this propeller in the case of engines of large horsepower. This fact alone will require reduction gearing of the propeller if the present trend of engine design continues; that is, if the rate of crankshaft revolution continues to increase.

An example may aid to clear this phase of the problem. Assume a 600-hp. engine rated to turn at 2400 r.p.m. installed in an airplane having a high speed of 150 m.p.h. Let the propeller be directly driven. By the ordinary method of design, the diameter of the propeller that would be required to absorb the horsepower at the given speed will be 9.25 ft. Table 2 shows that the limiting diameter for 2400 r.p.m. is 7.95 ft., which is considerably less than the diameter required to absorb the power at this rate of rotation.

TABLE 2—PROPELLER SPEED VERSUS LIMITING PROPELLER-DIAMETER ON ACCOUNT OF LIMITING TIP-SPEED CONSIDERATIONS

Speed, R.P.M.	Propeller Diameter, Ft. General Service Metal	Propeller Diameter, Ft. General Service Wood
1,000	19.10	16.20
1,200	15.90	13.50
1,400	13.65	11.60
1,600	11.90	10.15
1,800	10.60	9.02
2,000	9.55	8.12
2,200	8.67	7.38
2,400	7.95	6.75
2,600	7.35	6.24
2,800	6.83	5.80
3,000	6.37	5.41

Again let us assume a 600-hp. engine rated at 2400 r.p.m. installed in a plane having a high speed of 130 m.p.h. This would require a propeller diameter of 10 ft., which is much larger than that allowed by the limiting tip-speed. It would give a very inefficient propeller because of the incurred losses at the resultant high tip-speed. Tests have indicated that these losses vary from 5 to 10 and even greater percentages, depending upon the propeller design.

In multi-engine airplanes, the gain of performance attained by gearing, even though perhaps of small net value, may represent the difference between success and failure in the case of engine trouble during take-off and climb. The increased net efficiency very often, if not always, will for this reason merit gearing in the higher-powered multi-engine airplanes from the viewpoint of safety. However, from an engineering viewpoint, this advantage is small; it is one that may soon be solved equally well by the use of some type of variable-pitch propeller.

A somewhat questionable advantage is that the slower-turning geared-propeller probably will cause less vibration of engine and airplane structure and will thus prolong the life of the airplane in general. Experience

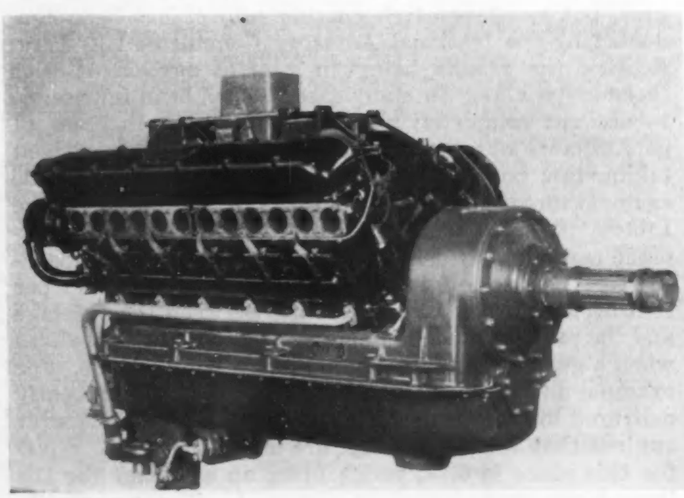
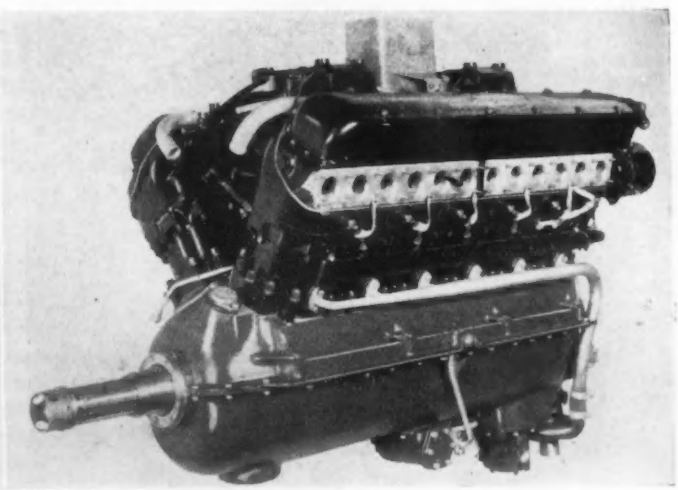



FIG. 3—GEARED AND UNGEARED CONQUEROR AIRCRAFT ENGINE
The Large Amount of Extra Material and Labor Necessitated by the Addition of Gearing Is Evident

has shown this to be true; although, at best, any gain from this source probably would be considered merely as incidental to the geared installation.

The conclusion is that the three contributing factors to the increased performance of a gear-reduction installation to which a quantitative analysis can be applied are (*a*), increased efficiency with increased v/ND ratio, which has been soundly established in quantitative form from various research and full-flight sources; (*b*) that the relation of fuselage-disc ratio to efficiency is reaching an analytical stage in the United States and in England and that the existence of such a relation is now commonly accepted by all propeller designers and (*c*) that the effect of tip speed upon efficiency of aircraft propulsion has received a vast amount of study and research in the last 10 years and that definite conclusions on this problem doubtless will be reached within the next year. Present data are in agreement with the facts given on this subject.

Disadvantages of a Reduction-Gearing Installation

The disadvantages of a reduction-gearing installation are widely varied but are commonly known. Perhaps the most obvious disadvantage is the increase of engine and propeller weight that necessarily accompanies the introduction of gearing. The weight control in the modern heavier-than-air craft is one fundamental limitation that governs the design characteristics of the airplane, and the addition of an extra 100 lb. can be made only after very careful consideration. The weight data shown in Fig. 2 result from a survey of the geared-engine field. It is evident that gearing-weight increase is not a function of horsepower entirely, neither is it a function of the type of gearing used but remains approximately a constant percentage of the engine weight; that is, to gear an engine involves an engine-weight increase averaging 10 per cent of the original engine weight.

Because of the larger propeller-diameter required, the propeller weight also increases from 10 to 20 per cent. This weight increase will not affect the high speed of the airplane to any appreciable extent, but it obviously reduces the rate of climb by an amount that depends on the relative power-unit weight to the total airplane weight. This loss of rate of climb because of increased weight is offset in varying degree by an increased propeller efficiency in climb resulting from the better climbing-pitch of the geared propeller.

A second disadvantage is the increased cost of the geared engine. Fig. 3 shows the geared and the ungeared Curtiss Conqueror engine and indicates the large amount of extra material and labor necessitated by the addition of the gearing. The number of changes to be made in the engine to allow for the gear installation depends upon the type of gearing to be used. The two types of gearing commonly used are the spur and the epicyclic. The additional cost of either type is about the same and does not become prohibitive.

The inefficiency of gear-power transmission causes a small loss of power that varies between 2 and 4 per cent, depending upon the type of gearing used. The loss of power output is 2 per cent for the spur gear and 4 per cent for the epicyclic type. Gear-reduction installation adds one more source of potential trouble to the airplane powerplant. This is an important factor which can be minimized only by the careful selection of materials and by expert workmanship in the construction of the gearing. Actual trouble from this source has been relatively small recently, and hence this too may not be considered prohibitive.

When To Use Reduction Gearing

In considering reduction-gear installation, several points should be emphasized. At best, such an installation is a compromise between the gains and losses involved, and the amount of net gain depends largely upon the particular engine and airplane combination and upon its design performance. Experience shows that the net gain does not warrant the gearing of engines rated at less than 400 hp., or for airplanes weighing less than 4000 lb. The type of airplane may limit the application of gearing because such an installation and the consequent increased propeller-diameter might require excessive additions to the landing-gear to secure proper ground-clearance. Airplanes having design values of $v/ND = 0.7$ or greater and at the same time having a propeller tip-speed less than the limit given, 1000 ft. per sec. for metal and 850 ft. per sec. for wooden propellers, would not give an increase of performance of sufficient magnitude to warrant the added complications. However, when the designed performance of an airplane does not come within the range of values stated, a designer should be hesitant about installing a direct-drive propeller.

Reduction-gearing is a refinement of design and, very often, a similar gain of performance can be obtained by using more care in attaining cleanness of the general-design characteristics of a given airplane. In the past, gearing has resulted in correcting poor basic design instead of giving super-performance to an originally so-called clean design. This fact should be realized by the aircraft designer before he finally decides to use gearing. So far as generalization on any engineering problem is permissible, we believe that the trend in large multi-engine transport-airplanes will be decidedly favorable to the use of gearing.

THE DISCUSSION

CHAIRMAN MAJOR LESLIE MACDILL[4]:—We have found that installing the additional radiator needed because of decreased slipstream velocity behind the geared propeller has caused an increase in the weight of the airplane and in one case caused a poor performance, although all indications led us to expect a better performance. In America, we have not used gearing as much as we should. A tendency has existed to give insufficient consideration to the subject, and many airplanes could have been improved by the use of gearing which were not so improved. With the development of the supercharger, which also will lead to the possibility of higher piston-speed and a higher number of revolutions per minute, the necessity for gearing propellers is becoming more and more important.

Whether we all appreciate the fact or not, one of the

[4] On leave from the United States Army and acting as technical adviser to White, Weld & Co., New York City.

factors in the past which has prevented higher engine-speed has been the difficulty of pumping the air into the engine at the high speed. The high piston-speed has made it very difficult to get full efficiency from the engine without using a supercharger.

After having built our experimental airplanes about the direct-drive engine and adopting them as standard after service test, along comes the geared engine and we have to consider, in addition to all of the questions of the advantages and disadvantages of the gearing, whether we shall have trouble with the cooling of the engine and whether we are likely to have trouble in installing the geared engine in the airplane without changing the flying characteristics.

From the viewpoint of the Government, which by that time will perhaps have procured a small number of direct-drive airplanes in service-tested quantities, changing to the geared engine is likely to delay production probably another year, which has made it a very difficult problem to decide. That has been one of the reasons that the adoption of the geared engine has been delayed. Therefore, I urge all engine builders who are considering engines of very high speed and the development of engines that are likely to be used principally in airplanes in which geared engines show decided advantages, to bring them out as geared engines and complete the tests early.

Gearing Depends on Engine Cooling, Not Size

H. CAMINEZ[5]:—Mr. Wright says that the efficiency tests of reduction gearing show power losses of 2 to 4 per cent, depending on the type of gearing used. How were those figures obtained? He says also that, according to experience, the net gain does not warrant the gearing of engines rated at less than 400 hp. I do not agree with Mr. Wright that experience has proved anything of the kind. It seems that gearing has been used mainly on large engines in this Country because all the development has been for military purposes and, for this work, the Government uses only large engines; however, a successful small, geared, radial air-cooled engine has been built in England, and our company has also built a successful reduction gearing for a small two-cylinder air-cooled engine of about 30 hp. These small gears were built because the increase in airplane efficiency that could be obtained with them showed that they were warranted.

It seems that the use of gearing does not depend on the factors that Mr. Wright mentions in his paper, but depends more upon the characteristics of the engine to which the gears are to be fitted. In the United States we have been slow to adopt propeller reduction-gearing because we use air-cooled engines here almost exclusively. In an air-cooled engine the propeller reduction-gear affects engine cooling and, if the power output of the engine is limited by its cooling capacity, the use of propeller reduction-gear would decrease the allowable engine horsepower. Engines having limited cooling cannot, therefore, safely be geared. Most of the present-day engines that have been developed for direct propeller-drive suffer in this respect, and I recommend that the cooling of an air-cooled engine be investigated before an attempt is made to gear it.

The weight per horsepower of the propeller reduction-gear depends more upon the running characteristics of the engine than upon the type of gear employed. If an engine is smooth and does not develop crankshaft whip, the reduction gear can be made considerably lighter than for a rough engine. Our company believes that the design of the reduction gear must be made to suit each individual engine design. A low weight per horsepower for the reduction gear can be obtained for some engines, but for others it cannot. The gears must be designed to stand up under the maximum torque of the engine, and the size of the gear does not depend directly upon the engine horsepower.

In all our tests we determined the loss in power of the propeller reduction-gear by ascertaining the rise in temperature of the oil going through the gears. Although this method is not accurate because the gear housing may dissipate some of the friction heat generated in the gears, no test equipment is available, to my knowledge, that will give this power loss more accurately. Our tests show that the gears we manufacture operate with a loss not exceeding 1 per cent of the engine power.

Pro and Con of Gearing Small Engines

THEODORE P. WRIGHT:—Our sources were British figures and actual power-losses on the test stand. The loss may be only 1 or 2 per cent. I merely wanted to emphasize that the loss in power is not very great.

There is the point that, as the airplane size increases, the ratio of powerplant weight to the total weight becomes less; in other words, the powerplant is a greater proportion of the total in small airplanes. If, therefore, we grant that the weight of the gearing is about proportional to the powerplant weight, then the increase in the weight of the gearing is proportional. The airplane weight is proportionally larger for a small airplane, so the benefits of improvements must be greater to justify such an addition of complication and possible source of trouble.

CHAIRMAN MACDILL:—One point in favor of the small engine is that it does not have excessive piston speed at a high number of revolutions per minute.

FRANK W. CALDWELL[6]:—So far, the small engines have not been run very much faster than the big ones. I know of only one small engine that runs at more than 2100 to 2200 r.p.m. Several 500-hp. engines run up to 2500 r.p.m. The propeller is very much smaller on the small engine, so the propeller-tip speed is slow and gearing is not needed for that reason.

A MEMBER:—In working out a gearing problem, I have found that one must assume a gear ratio and then work out the design. After building what seems to be the best design, the result is different from that which was expected.

EDWARD P. WARNER[7]:—As Mr. Wright and Mr. Johnson have pointed out, gearing has two entirely distinct functions; first, to make it possible to run a propeller safely without getting up to impossible or dangerous tip-speed and, incidentally, without creating a terrific propeller-noise that is intensely disagreeable; and, second, to increase efficiency, which may be quite as important for really low-powered and low-speed machines as for those of very much higher power, speed, and weight.

[5] M.S.A.E.—Chief motor engineer, Allison Engineering Co., Indianapolis.

[6] M.S.A.E.—Chief engineer, Standard Steel Propeller Corp., Pittsburgh.

[7] M.S.A.E.—Editor, *Aviation*, McGraw-Hill Publishing Co., Inc., New York City.

Marine Electrical Accessories and Wiring Problems

By C. V. Williams[1]

Motorboat Engineering Conference Paper

COOPERATION between the boat builder and the engine builder is needed to make boating free from the annoyances caused by defective and inadequate electrical accessories, according to the author. Generators are becoming overloaded and the engine builder should provide means for mounting larger generators capable of delivering 600 watts, this capacity being ample for medium-size cruisers up to 56 ft. in length; for larger craft a separate lighting plant is recommended.

Regulation of generator charging-current is important. The third-brush method has proved satisfactory for 100-watt generators, but external voltage-regulation is recommended for the 400 to 600-watt type. No more than 10 ft. of cable should be used between the starting motor and the battery. Straight manual control or fixed-spark ignition seems satisfactory, but engine backfiring can be somewhat reduced by using semi-automatic ignition-control. Ignition-coil waterproofing is increasingly important. Heavy cadmium-plating probably will eliminate most of the corrosive action of salt water.

A table showing suitable sizes of wire for the different types and lengths of circuit is presented which conforms with usual automobile and motorcoach practice. The author states that the introduction of specialized electrical equipment for motorboats will reduce the possibility of making service parts more available to the motorboat owner unless some way is found to facilitate the distribution of the parts.

IT IS IMPORTANT that the boat builder, as well as the marine-engine builder, should know something of the problems presenting themselves to the marine electrical accessory manufacturer; their cooperation is needed to free boating from the annoyances caused by defective and inadequate electrical accessories. Unless some solution of these problems is worked out, they will become increasingly harder to solve.

Generators are becoming overloaded. The present small 100-watt type is fast becoming suitable only in speed-boat and launch installations. It becomes necessary to introduce into the marine field a generator of larger capacity to take care of the cruiser type of installation. A 40-ft. cruiser powered with an outboard engine probably would invoke the wonder of anyone who saw it; someone might even say that it was underpowered. By the same token, we may well wonder at the "outboard-motor-sized" generator usually found on this type of cruiser. The owner expects this machine to deliver enough current not only to keep the battery charged for ignition and starting, but to light the cabin, deck lights and running lights, and to run fans, toasters and other accoutrements. So far as the maker of the generator on this engine is concerned, the job is to keep the battery charged for starting and to light three or four 3-cp. lamps, or the amount of work ordinarily to be done in speed-boat installations.

Larger Generators Needed

It therefore becomes necessary for the engine builder to provide means for the mounting of larger generators, which should be capable of delivering 600 watts, and necessitates using diameters up to 7½ in. This wattage would be ample for the medium-size cruiser, say up to 56 ft. in length. For larger craft, a separate lighting plant is recommended. If the same engine is installed in speed boats, the small 100-watt-type generator is still available, and this type of service is not being penalized because the larger-cruiser installations require more battery current. The boat builder's duty is to insist that the engine builders regard some of the present engine generator-mountings as obsolete and provide facilities for the installation of these larger generators.

One of the important factors is the regulation of generator charging-current. On the smaller 100-watt-type generator, the third-brush method has proved satisfactory; on the larger 400 to 600-watt type, the use of external voltage-regulation is recommended. Long runs at sustained high speed necessitate this procedure to prevent the overcharging of batteries, at the same time providing ample current from the generator when full battery-current is required.

Ignition and Waterproofing

The type of ignition becomes a matter of engine-builders' choice. Straight manual control or fixed-spark ignition seems satisfactory, but the hazard of engine backfiring can be reduced somewhat by using semi-automatic control of the ignition. Breakage of Bendix drives and drive housings, which renders the starting motor inoperative, seems greatest on engines using the full manual type of ignition because of the operators' failure to retard the spark at the moment of cranking.

Waterproofing of ignition coils becomes increasingly important; hence, Bakelite-encased coils will become more extensively used and probably adopted entirely.

Salt-water corrosion of electrical apparatus presents a problem not encountered in automobile practice, and some effective method to reduce it becomes necessary. It is questionable if any reasonable attempt has been made to solve this problem, but heavy cadmium-plating probably would eliminate most of this trouble.

Marine-Type Wiring

The wiring of boats rests entirely with the boat builder. We take exception in many cases to the use

[1] Sales engineer, Delco-Remy Corp., Detroit.

of wires that have insufficient carrying capacity. The wiring information in Table 1 will assist the boat builder in using wires that conform with usual automobile and motorcoach practice.

TABLE 1—SUITABLE WIRE SIZES FOR 12-VOLT-CIRCUIT MARINE INSTALLATIONS

	Gage No. Wire	Gage No. Cable	Total Length, Ft. Wire	Total Length, Ft. Cable
Generator	12	...	6 or less	....
	10	...	6 to 10	....
	8	...	10 to 25	....
	6	...	15 to 25	....
	5	...	25 to 50	....
Starting Circuit	..	0	......	6 or less
	..	00	......	6 to 7½
	..	000	......	7½ to 10
Horn	10	...	......	....
Lighting	10	Maximum of four 21-cp. lamps per circuit		
Ignition	12	With one coil		
	10	With two coils		
Fuel-Pump	12	With one pump		
	10	With two pumps		
Remote Control Switch	12	...	......	....

Efficient application of the starting-motor torque can be made best when the starting-motor cable is shortest. It is not unusual to find as much as 22 ft. of undersized cable running from the battery, amidships, to the switch on the toeboard in the floor of a speed boat and back to the starting motor. Voltage losses in the cable reduce the effectiveness of the starting motor to such an extent that it becomes inadequate. If this type of installation must be continued, the use of No. 000 cable is recommended, with a positive ground to the engine from the battery. However, it is recommended that no more than 10 ft. of cable be used between the starter and battery. The most satisfactory installation includes the use of a remote-control switch actuated by an electric solenoid. This eliminates many yards of cable, and cable rattles also.

Marine Servicing Difficult

An important and difficult problem that has not yet been solved is the servicing of marine electrical equipment. Remoteness of the average service station for boats is the main difficulty. The acuteness of electrical trouble in the motorboat demands more available electrical service than it is possible to give at present. Specialized electrical service is not available at all motorboat service-stations, and the electrical equipment must be sent longer distances for repairs than is true of automobiles; consequently, the time element involved is greater.

The original idea of the electrical-equipment manufacturer was to incorporate in most of the marine equipment parts suitable for the more widely used automobile systems, with the idea in mind of making these parts available to the motorboat owner. The introduction of specialized equipment for motorboats, however, will reduce the possibility of making service parts more available to the motorboat owner unless some way is found to facilitate the distribution of the parts. The electrical manufacturer is open-minded to suggestions from the boat builders as to the best method of increasing the availability of service to the boat builder and to the boat owner.

Photographic Records of Progress Board

THE PROGRESS office of the Triumph works is centrally situated in the main works and is fitted with a number of metal control-boards or panels around the walls. Each board corresponds to one model or to one of the main units and is divided into vertical columns corresponding to the different departments and operations through which this work passes, the component parts and part numbers being listed down one side of the board in the usual way.

All the boards are drilled to receive colored pegs in position corresponding to the location of the work, and it is claimed that, by recording movements of work from the bookers' slips, the position of any part or unit within the works can be seen within half an hour of the transfer of work from one department to the next. The bookers' slips are made out in duplicate, one copy being sent to the progress department and the other to the wages office.

It will be understood that the parts for various models are put through in batches, usually 100 in the case of the main components. During the dinner hour each day, all the progress boards are photographed, and large-scale prints are immediately prepared and sent to the works manager's office. Thus a permanent record of the movement of all work can be kept with comparative ease.—*The Automobile Engineer.*

Heredity and Environment

IT IS FOOLISH to discuss whether heredity or environment plays the greater rôle in life. One might as well ask whether food or water is more important to the individual. Both are indispensable, but their functions are different. Our heritage is Nature's gift, closing some channels, opening others; the conditions or influences which surround us, the education we are offered, is opportunity stationed ready to measure what we do with our endowments with yardsticks or relativity which vary with the case in hand.—Edward M. East.

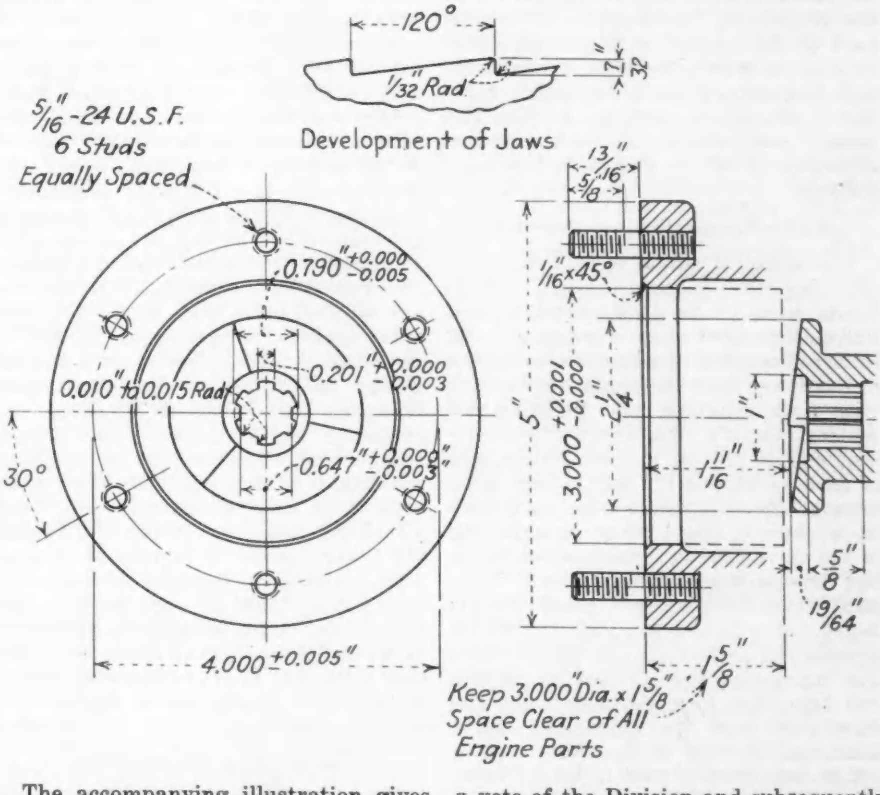
Standardization Activities

Aircraft-Starter Mountings

Adoption of Specifications for Small Size Recommended by Engine Manufacturers

THIS subject was one that was first taken up by the Aeronautic Division of the Standards Committee during the World War, but conditions were changing so rapidly at that time that no specification was adopted. The Division discussed the subject again at some length at its meeting in Philadelphia in September, 1926, and then felt that provision should be made on aircraft engines for standard starter-mountings for both electric and air starters, as the Army and Navy Conferences had sufficiently established practice to formulate such a standard. Members of the Division concluded, however, that it would be premature to decide upon a range of engine sizes, particularly of the smaller engines, to which such a standard should apply. But new developments occurred so rapidly that it was not until August, 1928, that a standard was adopted by the Society as printed in the current issue of the S.A.E. HANDBOOK.

Subsequent to the adoption of the present S.AE. specifications on aircraft-engine starter mountings, one of the manufacturers of small engines suggested that the adoption of specifications for a smaller-size mounting flange be considered, as at times it was impossible for manufacturers of small engines to satisfactorily use the larger mounting. At the time this was proposed at the meeting of the Aircraft-Engine Division, meeting in Chicago last December, some question was raised as to the need for two standard flanges for mounting this one accessory. Since that time, however, such a small flange has been manufactured and used, and the question has again risen as to whether the Aircraft-Engine Division of the Standards Committee should adopt specifications in line with this new flange.



The accompanying illustration gives the dimensions of such a flange as they may be submitted to the Aircraft-Engine Division for consideration. A survey of all the aircraft-engine manufacturers is now under way to ascertain whether a need exists for these specifications and, if so, whether the dimensions as shown are satisfactory. Upon the data received, a decision will be made whether the suggested standard shall be put to a vote of the Division and subsequently recommended to the Standards Committee.

Transportation Engineering

Valve and Bearing Reinstallation

Details of Engine-Overhaul Practices of Standard Oil Co. of California

METHODS of reconditioning the valves and main bearings of the motor-vehicle fleet of the company with which he is connected were given by M. C. Foster, of the Standard Oil Co. of California, in a paper presented at a joint meeting of the Service Managers Association and the Southern California Section of the Society in Los Angeles. The first part of the paper, on Engine-Overhaul Procedure, was printed in Transportation Engineering in the November number of the S.A.E. JOURNAL, p. 552. The second part, dealing with the reconditioning of valves and main bearings, follows:

Valve-Reconditioning Practice

Particular attention is paid to reconditioning the exhaust valves. Valve-heads must be in good condition, and valve-stems that show a wear of 0.003 in. are discarded. Exhaust-valve guides are renewed and the seats are reamed with both roughing and finishing reseating reamers. We favor a wide valve-seat and do not cut it down unless it is at least as wide as the face of the valve, because the object of a wide valve-seat is to prevent the cutting or grooving of the valve face so that the valve drops and lessens the valve push-rod clearance which, in time, will cause the exhaust valve to burn. Such procedure assures the correct seating of the valve and minimizes the amount of carbon and heat that blow down between the valve-stem and its guide and cause wear and sticking of the valve.

Less attention is paid to intake-valve reconditioning because these valves are kept cool by the incoming fuel mixture and the stems receive better lubrication. Old valves that are to be used again are refaced on a valve-facing machine; all valves are ground in, using lapping compound with a machine, and the valve-adjusting screws are sent to the grinders, with the cylinder-block, to be faced off square.

Refinishing Crankshaft Bearings

The crankcase is placed in the engine stand and the cylinder-blocks, which were detached, are bolted on. After placing the engine in an inverted position for main-bearing installation, the bearing caps are leveled on a surface plate covered with emery cloth. Undersized bearings are pressed into the caps and the crankcase and are dressed down. Each half of the bearing is allowed to project out of the cap or crankcase 0.003 to 0.004 in. so that, when bolted together, there will be a total projection of 0.006 to 0.008 in. to be compressed, which assures a firm seating of the bearing when it is in place.

A reamer bar is put into place and a feed-screw device—a ½ x 10-in. cap-screw threaded the full length and inserted through a ⅝-in. hole bored near one end of a ½ x 2 x 12-in. steel bar—is clamped to the engine stand with a C clamp. A nut having one end rounded is placed on the screw, round end first, and pulled up to the hole in the bar, and this makes a very serviceable feed when operated with a speed wrench. A fly-cutter driven by an electric drill is placed on the reamer-bar, the object being to save time in aligning and roughing, and the cutter is set to bore the bearing 0.005 or 0.006-in. less than crankshaft size in one cut. Each main bearing is bored separately and, when all main bearings are bored, the fly-cutter is replaced by a reamer head carefully set to cut exactly crankshaft size or slightly less and operated in the same way. A fly-cutter is not used for finishing because of the difficulty of setting it to cut to a predetermined size, but a reamer easily can be set to cut a smooth accurate hole.

Running-In the Bearing

When the foregoing operation is completed, the crankshaft is put into place and each bearing is bolted down and tested individually for tightness. A 2½-ft. leverage and a 10-to-50-lb. pull, according to bearing size, are used in testing. All main bearings are then bolted down and the engine is connected to the running-in machine through a driveshaft and two universal-joints, the machine being started in low gear at about 160 r.p.m. and operated for about 30 sec.; it is then shifted to high gear, about 360 r.p.m., and run about 1½ min.

During this process no lubricant is applied and the bearings become warm; oil is then applied freely and, after 10 min. of operation, the machine is stopped. This burnishing has packed or settled the babbitt, leaving a hard smooth bearing that has for an engine equipped with a cast-iron crankcase a running fit and no measurable clearance. The reason is that the heat generated by friction of tight bearings expands the crankshaft but is resisted by the iron crankcase and, since the expansion coefficient of steel is greater than that of cast iron, a very slight clearance exists between the crankshaft and the bearings when cold. The reverse is true of engines having aluminum-alloy crankcases, because the coefficient of expansion of the metal in the crankcase is greater than that in the crankshaft; therefore, after the burnishing operation it is necessary to hand-scrape lightly the whole bearing surface to make it possible to crank the engine easily. It should be borne in mind that a shaft running in bearings supported by an iron crankcase has less bearing clearance when hot than when cold, and that in an engine having an aluminum-alloy crankcase the reverse is true, which seems to explain why main bearings are replaced more often in aluminum-alloy than in cast-iron crankcases.

Refitting Connecting-Rod Bearings

The fitting of bronze-back connecting-rod bearings is done in much the same way as for the main bearings, the connecting-rods being held in a reaming fixture to which has been added a feed screw that can be operated with a speed wrench. This machine has two shafts, one for the fly-cutter and the other for the finishing reamer, turned by an electric drill. As the crankshaft throws are all ground to one size, one tool-setting is all that is necessary. The time required to set up, bore, ream and remove a connecting-rod from the machine is not more than 4 min. Connecting-rod bearings are quickly filleted and faced off with special tools in a drill-press.

The connecting-rods are assembled to pistons and aligned, and then are placed in the engine and burnished, as were the main bearings. A connecting-rod bearings always can be finished without shimming or scraping. Bearings which are cast into the connecting-rods are bored to exact crankshaft size by the company which does the rebabbitting and, for this purpose, the crankshaft is sent with the rods. Burnishing, by which means a full bearing without excess clearance is obtained, gives dou-

(*Concluded on p. 678*)

Production Engineering

Welding-Procedure Control[1]

Materials and Procedure for Production Welding Should Be Determined by Management

SOME precautions are to be observed in handling oxy-acetylene equipment to prevent injury to persons who might come in contact with the equipment or materials. Distribution of the National Safety Council's Safe Practices Pamphlet No. 23, and other publications in which the necessary precautions and safe practices are presented in detail, has served as a reminder of the importance of that phase of welding. As a result, the industry has maintained a splendid safety record in spite of the steadily increasing use of oxy-acetylene welding. Let me emphasize again the importance of insisting that only standard equipment, approved by the Underwriters' Laboratories, be used, and that all installations be made in accordance with the regulations of the National Board of Fire Underwriters.

One point that deserves special consideration is fires resulting from failure to take proper precautions in using oxy-acetylene equipment. In every case that has been brought to my attention these have been preventable. It is realized that oxy-acetylene equipment is frequently used, particularly in repair and maintenance, under conditions which are far from ideal. Use of welding or cutting apparatus under such conditions demands that those in charge make certain that every possible precaution be taken to meet any emergency that might develop. Most important to guard against are the sparks and drops of hot slag produced during the cutting operation.

Developments during recent years have focused attention on another phase of safety in the welding industry; that is, the safe application of welding in the fabricating of products and structures whose strength depends upon the strength of the weld. During the early days of welding, certain enthusiasts attempted application of welding where it should never have been tried and in some cases applied welding to shells of boilers and other pressure vessels without knowing anything about boiler design or metallurgy. Failures resulted, and such failures were of course a setback to the industry. They resulted in some rulings prohibiting the use of welding for certain applications. Probably this was a good thing, for I have always found that regulatory bodies are willing to change their rulings when they can be shown that the change is justified. Probably the day will come when various bodies that have regulatory powers will insist that welding on important work, where the strength of the part of structure is dependent upon the strength of the weld, be done only by persons who are licensed or have a permit. It is well to remember that, even today, certain welding applications should not be attempted.

Uniform Excellence Through Control

Thorough study by engineers of the subject of safe welded construction in production work has resulted in the development of methods whereby this can be assured. When first introduced, welding was used mainly for repair work, and the details of handling each job were left entirely to the individual welders. Later, when welding began to be applied as a production process, it became evident that the determination of the various factors could not be left to the individual welder but demanded managerial control. Until then, success in welding had seemed to depend mainly on the skill of the individual welder, and experience had shown wide variation in skill and ability. Slight variations were not objectionable for certain products, but it was essential that the management have some way of making certain that important work, in which the question of safety to the ultimate user was involved, be always of uniformly high quality.

Various factors involved in production welding were made the subject of careful engineering investigation, the first study being made in 1924 in connection with the installation of long welded pipe-lines for carrying gas and oil at high pressures. It was found that the success of any welding application can be assured if proper attention is paid to six factors. Determination of the details regarding these factors, for any given type of work, forms a procedure control, or master guide, from which the specifications for any specific job of that type can be written. The six factors of a procedure control are:

(1) *Check of the Welders.*—To see that only competent operators are used, and that they prove their ability by successfully passing qualification tests simulating the particular operation. It is advisable to test welders on all work, even unimportant work, so that they will be prepared to do important work later as the occasion may arise. Periodic testing of welders is advisable. As an operator gains experience, he develops his own ideas and may be unconsciously deviating from best practice. Periodic testing will make certain that the welder's skill is maintained and that his work is of uniformly high quality.

(2) *Selection and Inspection of Material.*—To make certain that only material suitable to welding is used and that correct welding-rod is selected

(3) *Design and Layout of Welded Joint.*—To make sure that the joint is correctly designed for welding

(4) *Preparation for Welding.*—To see that preparation and assembly are of the best for the purpose

(5) *Organization and Welding Technique.*—To see that the work is carried on in the most satisfactory and economical way and that the welding itself is correctly done

(6) *Inspection and Test.*—To check whether the foregoing items of the welding procedure have been followed, and to see that proper welding results. The test of the completed work is an additional assurance that the welding installation will give satisfactory service.

Application of procedure control to a wide variety of welding work has produced such uniformly satisfactory results that the idea is rapidly becoming recognized as one of the most important developments in assuring safe welded construction.

Welded Joints in Steel

Almost all grades of steel can be readily welded, with suitable procedure and the correct welding-rod. Oxygen-welded joints of high strength and ductility can be made by operators who are experienced. Welding-rods of three grades have been in common use for welding steel. These are of Norway

TABLE 1—STRENGTH AND ELONGATION OF WELDED JOINTS

	Tensile Strength, Lb. per Sq. In. Design Factor	Tensile Strength, Lb. per Sq. In. Ultimate	Elongation in 2 in., Per Cent
Norway Rod	42,000	50,610	9.3
Mild-Steel Rod	41,000	49,800	9.8
Nickel-Steel Rod	48,000	58,600	7.6
High-Test Rod	52,000	61,800	7.8

[1] From a paper presented by Orlie Trentham, of the Linde Air Products Co., at a meeting of the S. A. E. Club of Denver.

iron, mild steel and nickel steel. Another, known as high-test rod, has been on the market for several years and has been remarkably successful. Selection of a satisfactory welding-rod is essential to good welds. This is of importance because only correct welding-rods produce weld metal of the required physical properties.

Most of the carbon, which is the principal strengthening element in steel, is burned out of the Norway-iron and mild-steel rods during the welding operation. Therefore, weld metal from these rods has relatively low tensile-strength but is soft and ductile. Weld metal from the nickel-steel rod has characteristic hardness and strength because of its nickel content. The silicon and manganese in the high-test rod combine to form iron-manganese silicate, which floats to the surface in the form of a thin film of slag and protects the molten metal from oxidation, preserves its carbon content, and prevents the formation of the carbon monoxide which might cause blow-holes. Thus, a strong high-grade steel is formed in the weld. Typical tension tests made upon welded-plate specimens ½ in. thick, having single-V welds made by trained welders with the four different rods mentioned, have shown average strengths as listed in the ultimate-strength column in Table 1.

Ultimate strengths equal to those shown in Table 1 may be expected from joints made by experienced welders under proper procedure control. Maximum design values should be somewhat lower than these, to be on the safe side. The strengths shown in the first column have been accepted by a number of welding engineers for design in general structural work.

Low-carbon steels, containing not over 0.25 per cent of carbon and including all common structural plate and shapes, are subject to a coarsening of the grain to a distance of about 1½ in. on each side of the weld. Fortunately, the tensile strength of such steels is little affected by this change. Samples in which the welds are stronger than the base metal will ordinarily break at some distance from the joint and not consistently within the heated zone. The effect of the heat is more serious with higher carbon-content.

It is still necessary to convince engineers that uniformly high results are possible at the hands of the average workman. Some time ago, 78 welders, working for American railroads, made up tension-test pieces in which both Norway-iron rod and high-test rod were used in single-V welds on ⅜-in. boiler-plate. The average strengths were 47,000 lb. per sq. in. with Norway-iron rod and 58,000 lb. per sq. in. with high-test rod, the difference of 11,000 lb. between welds with the two kinds of rod being almost uniform.

Economic Size of Production Lots

An unfortunate error was made in printing Prof. Fairfield E. Raymond's paper on the above subject in the S.A.E. JOURNAL for November, 1929. Item 4 in Table 4, p. 459, should read:

(4) Subtract k_p/D from $1/S$

The author justly claims as an advantage of his mathematical method that a single letter can be made to express the meaning of a whole paragraph. In this instance, the substitution of s for S made a correspondingly important error in the meaning, as s denotes the space charge per year and S indicates the consumption rate.

Professor Raymond writes that a note should be added to the definition of item t, in Table 3 of his paper, which was used to designate unit production time, in days. The footnote should read:

> If the value for the consumption rate S is not to be expressed in pieces per day, when inserted in any one of the formulas, but expressed in pieces per week, month or year, the value of t in days should be divided by the standard number of working days per week, month or year, to conform with footnote 3.

Transportation Engineering

(*Concluded from p. 676*)

ble the length of life that any other method of finishing gives.

Further Details of Procedure

At this time a general assembly is made of the camshaft, timing gears or chains, water-pump, oil-pump and generator. The cylinder-head, timing-gear case, valve cover and crankcase pan are left off. The burnishing machine, which now becomes a running-in machine, is started to test the timing gears for quietness and to see that everything is as it should be. The cases are then bolted on and the engine is turned right-side up. The carbureter, ignition units, governor, controls, fan, clutch and transmission—if it is a unit power-plant—are reinstalled. Oil is supplied and the engine is run by outside power for about 2 hr. This is a valuable operation because it thoroughly distributes the oil throughout the engine. Heat generated by the compression will warm the engine to a temperature comparable with that obtained under normal operation.

A gasoline tank fitted with brackets by which it can be hooked to the engine stand without bolts is then put into place, and a battery is similarly placed. The battery is used for ignition, unless the engine has magneto ignition, and for the operation of an auto-pulse fuel-pump which supplies the gasoline through a flexible line to the carbureter. A 15-ft. length of water hose is fastened to the engine and a similar hose conducts the hot water away. A 5-ft. piece of flexible tubing is connected to the exhaust manifold.

Running-in Reassembled Engine

The engine is started by the running-in machine and is then removed to a location where the exhaust is carried to the outside of the building. The engine speed is confined to a medium low-speed for about 2 hr., after which the governor, on truck engines, is set for the proper vehicle speed and the engine then run at full governed speed for at least 8 hr. Passenger-car engines are run at 1500 to 2000 r.p.m. for the same period, after which the cylinder-head, cylinder-block and crankcase bolts are tightened and the valves given a final adjustment for clearance. Experience has shown that the valve clearance recommended by the manufacturer is not always sufficient; therefore, valve clearance is determined by multiplying the length of the intake stem in inches by 0.001, and by multiplying the length of the exhaust stem in inches by 0.0015 to 0.0020, depending on whether the stem is for a passenger-car or a heavy-duty motor-truck engine.

Plenty of valve-stem clearance and wide valve-seats are conducive to freedom from valve trouble. On certain L-head engines, virtually no provision is made for the lubrication of the valve-stems, and this has caused considerable valve trouble. As a remedy, the crankcase breather is wholly or partly closed, and holes are drilled from the valve-spring chamber into the crankcase. The valve cover-plates are drilled and the engine is forced to breathe through the valve-spring chamber. Oil vapor in sufficient quantities is thus obtained to correct the valve trouble.

The cycle of operation for rebuilding engines as described is operating very successfully. Our object is to build as well as or better than the manufacturer does, as each engine can be given individual attention, and to do it with the minimum of replacement parts and labor.

Interesting Western Aeronautic Meeting

Two Evening Sessions in Los Angeles Well Attended—Good Papers on Aircraft Design, Operation and Research Presented

TAKING its place in the galaxy of aeronautic events held in Los Angeles last month, the Western Aeronautic Meeting of the Society was held on Nov. 12 and 13, in the ballroom of the Alexandria Hotel. It had been preceded on Nov. 8 by a three-day Airport Conference under the auspices of the Aeronautical Chamber of Commerce of America, culminating in the opening of the Western Aircraft Show the following day.

This combination of events drew to Los Angeles a large number of airport men and aeronautic engineers, in addition to a considerable number of people necessary to carry on the activities at the show. The Western Aircraft Show provided excellent displays of aircraft, engines and accessories. From the engineering viewpoint, the most interesting exhibit was that of a Fokker Super-Universal plane equipped with a variable-pitch propeller, which was exhibited outside of the main building on a small runway, on which the airplane could be taxied. The demonstration consisted of running the ship along the ground, reversing the pitch of the propeller and backing it up, in much the same way as one would an automobile.

The Airport Conference afforded the delegates an opportunity to visit the various airports in and around Los Angeles, part of the transportation being by air.

Dinner Attended by About 350 Persons

The meeting of the Society, which was sponsored by the Southern California Section, opened on Tuesday night with a dinner attended by approximately 350. Commander E. E. Wilson, Chairman of the Aeronautic Division of the Southern California Section, was to preside as toastmaster, with Harry A. Miller acting as chairman of the technical meeting. However, as it was necessary for Commander Wilson to go to sea unexpectedly, he was unable to be present, and Ethelbert Favary, of the Moreland Motor Truck Co., acted as toastmaster in his stead, as well as chairman of the meeting in the absence of Mr. Miller, who was unavoidably detained out of town.

In addition to the speakers, the following guests occupied places at the speaker's table:

Amelia Earhart, assistant traffic manager, Transcontinental Air Transport
L. K. Bell, general manager, Aeronautical Chamber of Commerce of America
Lieut. A. H. Kager, U. S. N., Commandant, Naval Reserve Base, Long Beach, Calif.
Lieut. C. B. Hayser
Major E. E. Aldrin
W. H. Beck, western traffic manager, Transcontinental Air Transport
Cliff Henderson
William H. Fairbanks
J. J. Canavan
Eugene Powers
T. C. Patton
Eustace Moore
C. H. Jacobson
Ethelbert Favary
A. J. Underwood

Papers Presented the First Night

Following the introduction of the guests, Commander Wilson's paper on the Trend in Aircraft-Engine Design was read by Gerard Vultee, chief engineer of the Lockheed Aircraft Co., and Secretary of the Aeronautic Division of the Southern California Section.

This was followed by a short statement by Leigh M. Griffith, vice-president of the Emsco Aero Engine Co., on the situation relative to Diesel engines and then by the presentation by Edward T. Vincent of a paper on Diesel Aircraft-Engines.

George Cain, field manager of the Transcontinental Air Transport, discussed in detail the system of maintenance involved in the care and repair of aircraft engines for transport work, with particular reference to the system in use by the Transcontinental Air Transport. Much interest was evinced in this paper, which was followed by discussion on this and the other two papers previously presented.

ETHELBERT FAVARY

A Prime Mover in Arrangements for and the Conduct of the Meeting, Who Officiated as Toastmaster at the Aeronautic Dinner in the Absence of Commander Wilson and Presided as Chairman of the Ensuing Technical Session

Second Evening's Interesting Program

The evening of Nov. 13 was devoted to a session on Air Transportation and Engineering, with an attendance of approximately 125. The chairman was L. M. Griffith, and the first paper was presented by Harold Crary. This was a paper written for this meeting by W. E. Boeing, on Night Flying with Mail, Express and Passengers.

A very interesting treatise on High-Speed Transport Planes was given by Gerard Vultee, who dealt with the latest developments in the construction of fast passenger-carrying craft, and the requirements and design for high speed in operation.

The new wind-tunnel at the California Institute of Technology, which is one of the largest in the Country, is expected to occupy an important position in the experimental work attendant upon aircraft design. It was illustrated and described in a paper by Clark B. Millikan in the S.A.E. JOURNAL for November, p. 520. A highly instructive and entertaining paper on The Wind-Tunnel as an Engineering Instrument, by Dr. A. L. Klein, assistant professor of aeronautics at the Institute, provided material for considerable discussion.

Harris M. Hanshue, president of the Western Air Express, prepared for the meeting a paper on Long-Distance Passenger Transportation which was delivered by C. W. H. Smith, general traffic manager of this airline, who answered a large number of questions that were evoked by his talk.

The success of the entire meeting was evidenced by the attendance of many prominent aeronautic engineers and by the great amount of interest in the discussion. A great deal of credit is due to the officers of the Aeronautic Division of the Southern California Section and to Ethelbert Favary for the planning and conduct of the meeting.

Summaries of the papers presented follow:

Bases of Engine Comparison

Commander Wilson, in his paper, classifies engines as to (*a*) form, (*b*) method of cooling, and (*c*) method of using the

fuel, and under each heading lists the various types. That we may properly compare the different types, it is essential that a yardstick or basis of comparison be established, and with this in mind the author enumerates six requirements for which it is generally accepted the aircraft powerplant manufacturer must strive. He differentiates between powerplants for the buoyant aircraft and heavier-than-air craft, and as the requirements mentioned are somewhat elastic and indefinite, he defines them specifically. Referring to the influence of weight, the author states that the expression "pounds per horsepower" is itself indefinite, as the power output varies with the crankshaft speed and is a measure which can be properly applied only when qualified by statement of the crankshaft speeds.

Weight per cubic inch of piston displacement is a useful basis of comparison and shows that as engines decrease in size they do not decrease in weight in direct proportion, as the accessories constitute a larger proportion of the fixed weight in the small engines. A chart in which volumetric piston displacement is plotted against engine weight shows conclusively the superiority of the nine-cylinder single-row radial engine over the twelve-cylinder 60 deg. V engine. The difference is even more apparent when the radial engines are similarly compared with water-cooled engines.

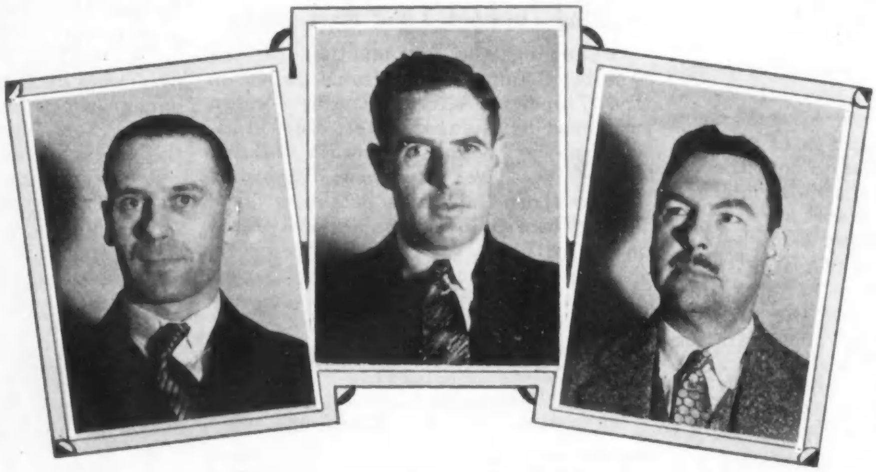
In buoyant aircraft, a 10-per cent improvement in fuel economy may result in a large reduction in gross weight, while an equivalent reduction in fixed powerplant weight might produce comparatively little reduction in gross weight. In an airplane, however, a considerable reduction in gross weight might result from improvement in the powerplant weight. No fixed measure can be established, according to Commander Wilson.

The powerplant cost seemingly involves many variables, and may be divided into initial cost and operating cost. Quantity production has a larger influence on initial cost than has design, but ease of maintenance and durability enters into the problem of operating costs. The form of the engine and the method of cooling are the two important factors.

Fuel economy, which is important because of its bearing on pay-load, is a function of both powerplant and airplane design, as well as choice of the propeller. Engine economy is a function of the expansion ratios that can be employed, but these are dependent upon the kinds of fuel employed.

The engine itself, the powerplant as a whole, and the effectiveness of ground organization, are the three factors in powerplant dependability that must be kept in mind, asserts the author. Accessibility of all engine parts greatly influences the ease of maintenance upon which reliability depends, and the cost of maintenance and the durability of the engine.

After comparing the various types of engine on the foregoing bases, Commander Wilson concludes that the direct-cooled single-row radial engine is generally advantageous, and that the heavy-oil engine should not suffer by comparison with the gasoline engine, but should profit from reduction of fire hazard. The analysis, therefore, points straight to the continuous development of the oil engine, and the sign posts of progress clearly indicate the path to be followed.



Speakers at the Dinner Session of the Western Aeronautic Meeting

Edward T. Vincent (Left), Who Presented a Paper on Diesel Aircraft-Engines. George Cain (Center), Who Described in Detail the Engine Inspection and Maintenance Methods of the Transcontinental Air Transport. Leigh M. Griffith (Right), Who Talked about Applications of Diesel Engines to Aircraft and Served as Chairman of the Second Evening's Session

Corrects Wrong Diesel-Engine Ideas

The paper by Mr. Vincent is confined to an attempt to eliminate some erroneous impressions regarding high-speed Diesel engines entertained by numerous engineers unacquainted with the latest developments in this field. In a table shown on the screen, a sport plane powered with a 300-hp. engine and a large transport plane of 200 hp. were compared to show that, while the fuel saving is slight in the small plane with relation to other operating expenses, the saving on the large transport amounts to $21 per hr. in operating cost and also saves 150 lb. per hr. of flight in the weight of fuel carried. This weight saving would increase the actual pay-load by the equivalent of three or four additional passengers. Another outstanding advantage of the Diesel engine is the possibility of developing a two-cycle engine.

To dispel the wrong impression that it is necessary to employ maximum pressures of the order of 1200 lb. per sq. in. and that the engine weight must be increased over that of the gasoline engine, the author points out that in actual practice it has been proved satisfactory to employ the dual cycle in which a certain proportion of the fuel is burned at constant volume and the remainder at approximately constant pressure. By this means it is possible to use maximum pressures from about 500 to 1500 lb. From a table of pressures, horsepower and fuel consumption and from other recently published data the conclusion is drawn that a fuel economy of 0.40 lb. per b-hp-hr. can be obtained at high speed at a maximum pressure of 800 lb. per sq. in. or less. In very high-speed oil engines the higher pressure is asserted by the author to be a direct advantage, as the gas pressure cushions the inertia loadings of the reciprocating parts and causes lighter bearing-loads. In two-cycle operation the gas pressure will produce a smoother engine.

Stating that the power developed by the engine is one other factor which influences the final weight, Mr. Vincent compares the yield in brake mean effective pressure of the modern gasoline engine and present high-speed oil engines, which have a usual overload capacity of about 15 per cent for about one-half hour. Assuming a gasoline engine weight of 1.5 lb. per hp., the oil-engine weight becomes 2.1 lb. per hp., or 40 per cent more, which must be offset by reduced fuel consumption.

Performance curves of the Junkers opposed-piston two-stroke oil engine were shown to indicate that this engine seems to perform as well as a four-cycle engine and has a fuel consumption of 0.40 lb. per hp-hr. at 850 r.p.m. No reason is apparent why the weight of such an engine cannot be reduced to that of the modern gasoline engine, according to the author; if this can be done, a great step forward in automotive engines will be made.

The remainder of the paper deals with operation and maintenance of the high-speed oil engine.

Owing to absence of data on such engines applied to airplanes, the discussion of these factors is based on other services. The conclusion is reached that we can look forward confidently to early realization of the fuel-injection aircraft engine capable of effectively competing with the present type of gasoline engine in all but the smallest sizes and offering marked advantages in the large units required for commercial air-transport.

Keeping the Engine Running

George Cain's talk was a detailed description of the engine-maintenance methods followed by the Transcontinental Air Transport. Overhauls made by this organization, said the speaker, are turning out engines that would have the approval of the strictest factory inspector, as the tolerances are virtually the factory tolerances and the rebuilt engine is as good as when new.

Only one thing keeps an engine running, and that is proper maintenance, according to Mr. Cain. The modern pilot, however, favors his engine in every particular.

Because the flying time between Los Angeles and Clovis, N. M., is 16 hr. for the round trip, the inspection periods are on a basis of 16-hr. units. Extent of the inspection and work done varies with the interval, a thorough inspection of every part of the powerplant being given after each 96-hr. interval. By means of a celluloid stencil placed over the inspection card, the parts that are not to be inspected at the first, second, third and subsequent inspections up to the complete one are marked out. Powerplant inspections start at and include the engine mount and embrace all accessories of the engine. Thus, the fuel system is individually examined from the fuel tanks to the carbureter; then the ignition system, including generator for the starter battery and wiring and spark-plugs, is separately gone over; and so on.

Inspection starts as soon as the airplane taxies up to the hangar, but before the second pilot leaves the cockpit he has entered on the pilot's report card any troubles or defects noted on the trip. The chief night mechanic tests each of the three engines to see how it is functioning and fills out a report; with this and the pilot's report to serve as a guide he starts his inspection of the engineer.

After giving details of the inspection and maintenance work, Mr. Cain remarked that it is costly but that careful planning will go far toward reducing the cost. Supplying the men with the right tools and shop equipment will also help, and refraining from having a mechanic do helper's work is important as regards cost. A good trouble-shooter can save much time in finding the source of trouble and so avoid delaying the departure of a plane.

PROMINENT GUESTS AND A SPEAKER AT THE LOS ANGELES AERONAUTIC MEETING
W. H. Beck (Left), Western Traffic Manager of the Transcontinental Air Transport. Lieut-Commander L. B. Richardson, U. S. N. (Center). Harold Crary (Right), Who Read a Paper by W. E. Boeing on Night Flying with Mail, Express and Passengers

The largest cut in maintenance cost can be made by redesigning the engine installations, said Mr. Cain; for example, providing cowl-fastening means that can be released in less than 45 min.; providing a large cock instead of a small drain-plug in the bottom of the oil-tank; and making vital fittings accessible for easy inspection.

In conclusion he asserted that there is no reason why the engine mount, oil tank, propeller and even the cowling cannot be assembled as a unit that can be released for removal by taking out a few bolts. This will be done eventually, but the time to do it is now.

Need More Night-Flying Aids

Mr. Boeing's paper emphasizes the need of developing all possible facilities and safeguards for night flying so that airplanes can carry their loads by night as well as by day. Statistics of commercial travel in this Country and Europe are given, as are also data on the progress made in airway and landing-field lighting by the Department of Commerce. Airplane equipment to aid the pilot when flying at night is described and information given regarding radio direction-beacons and radio communication.

With improved engines and equipment and accumulated operating experience, the Pacific Air Transport has increased the "laps" on the transcontinental route from Chicago to San Francisco from a length of 400 miles to 900 miles. The lessons learned are invaluable because, in Mr. Boeing's opinion, the industry is heading into an era of expansion that will dictate the everyday use of aircraft in a larger movement of passengers as well as mail and express. He predicts that passenger transports of the future will be larger, faster and more comfortable than was dreamed of a few years ago, and concludes with the statement that

THREE OF THE SPEAKERS AT THE SECOND NIGHT'S SESSION
Dr. A. L. Klein (Left) Presented a Paper on the Wind-Tunnel as an Engineering Instrument. Gerard Vultee (Center) Gave a Paper on High-Speed Transport Planes. C. W. H. Smith (Right) Read the Paper by Harris M. Hanshue on Long-Distance Air Passenger Transport

the American has a complex for rapid handling not only of his person but of his goods, and the assertion that to give him the maximum speed of transport will require that night flying be made as common and safe as daylight flying.

High-Speed Transport Planes

Several basic considerations make the use of high-speed airplanes absolutely necessary for the successful operation of an airline, asserted Mr. Vultee, who outlined these conditions. To illustrate the possibilities of effecting savings in operating costs with higher cruising speeds, he made a comparison between two planes powered with similar engines and carrying the same pay-load but having cruising speeds of 120 and 150 m.p.h. respectively. The faster plane would cover the same distance as the slower one in 80 per cent of the flying time, save 20 per cent in engine maintenance and depreciation, and 20 per cent in fuel cost. As engine maintenance and depreciation plus fuel cost amounts to 20 per cent of the total cost of operation of an airline, a reduction of approximately 4 per cent of total operating costs would be possible by the use of the faster equipment.

The faster plane, which also has a better rate of climb, good reserve power and maneuverability, is safer to operate in bad weather over difficult country, continued Mr. Vultee.

Some of the engineering requirements in designing high-speed airplanes which the Lockheed company had found in its own experience to be basic were stated to be the absolute necessity of keeping the size of the airplane as small as is practically possible, the use of resilient landing-gear suitable for high-speed landing, easy and effective surface control at stalling speeds so that the pilot can take full advantage of the possibilities of "mushing" the plane into a small field, and, finally, choice of a wing section such that the maximum lift coefficient can be obtained with the least sacrifice of other aerodynamic characteristics. With proper attention to the foregoing, said Mr. Vultee, it has been found possible to run up to wing loadings of 16 to 17 lb. per sq. ft. and still maintain practical landing characteristics.

The rest of the paper was devoted to consideration of a fuselage form and construction that result in small size, light weight and the minimum air resistance, and of cowling the radial engine to reduce drag. Development work in the last 10 months on an N.A.C.A. type of cowling has resulted in a cowl that cools the engine satisfactorily and increased the high speed by 20 m.p.h. Duralumin was found to be the best cowl material because of its strength and light weight. Observation showed that the cowling has a tendency to smooth out the air-flow along the fuselage and tail surfaces and that the empennage controls seem smoother and more effective. The installation of complete cowling increases the tendency to "float" while landing, but the pilot soon learns to correct this in his handling of the plane when bringing it to the ground.

Uses of the Wind-Tunnel

Dr. Klein disclaimed that the new wind-tunnel at the California Institute of Technology has influenced aircraft design, no work having as yet been done in it on airfoils or airplanes, as it is still in the calibration stage. At some time in the future, however, some work for the industry can be done, it is hoped. The address was confined mainly to pointing out some of the possibilities in wind-tunnel testing.

The only way in which the lift, drag, center-of-pressure travel and mean aerodynamic chord of a tapered wing-section can be determined, asserted Dr. Klein, is to construct an airfoil and send it out for test. More test work is needed on the movement of the center of pressure outward on a tapered wing as the angle of incidence increases. It is highly desirable, also, to determine interference of the wings and fuselage by investigating the wings independently. In this connection, some work recently done in Germany has shown that the proper filleting can greatly reduce the losses due to interference.

In a large wind-tunnel it is possible, said Dr. Klein, to test full-scale landing-gears and similar constructions. A few tests on struts with small angles between them will, he believes, be very illuminating as showing their bad effects.

A need has arisen for drag-increasing devices on very high-speed airplanes, because the gliding angle is so flat that any reasonable glide angle will cause the plane to pick up speed. The investigation of some form of device that will not spoil the lift but will produce a large increase in drag is an ideal wind-tunnel problem.

High-lift devices should always be investigated by airfoil tests to ascertain their effectiveness.

Very little work has been done on airplane stability with power on. Tests of dynamic stability require an entirely different type of set-up from that for tests of static stability. A model is required that is dynamically similar to the full-scale airplane and it must be allowed to oscillate in the different ways possible.

The flutter problem has been investigated in wind-tunnels and some important criteria for design have been obtained. Another important problem of the designer that can be studied in the wind-tunnel is the propulsive efficiency of the propeller.

Rail and Air Transport Compared

Any delusions that the day of the airplane as a passenger carrier has arrived were dissipated in the reading by C. W. H. Smith of the paper on Long-Distance Air Passenger-Transportation written by Mr. Hanshue. The author makes a very frank comparison of passenger transportation by rail and by air. He states his belief that any air transportation system designed to give valuable service must reach to distant points and do so in a short time. Because it is capable of doing both, the airplane is certain to find favor as a transport machine, but he believes the day of airplane travel is just dawning. The eyes of those who have declared that it has arrived "have been deluded by the miasma of specious accomplishments," in the words of Mr. Hanshue. Nevertheless, the airplane has accomplished more within a very few years as a passenger carrier than has any other transport medium in a similar length of time.

As the airplane and the railroad train must closely parallel each other as mediums for the transport of passengers in fast time, the early days of the steam train are pictured vividly by quotations from San Francisco papers of 1855.

The steam train as a passenger carrier has now reached the age of more than 80 years in America; the airplane as a passenger carrier is less than 4 years old. Yet the average speed of the train today is between 30 and 40 m.p.h., whereas the average passenger airplane travels at 100 to 125 m.p.h. Within five years, believes Mr. Hanshue, airplanes will be transporting passengers across the United States, a distance of approximately 2500 miles by air, in 12 hr., possibly at a fare of $50 per passenger.

Two essentials to make this possible are an air-minded public and airplanes that can maintain a cruising speed of more than 200 m.p.h. One of the problems will be to perfect an engine that will produce more energy per pound of weight, so that it will be possible to make the transcontinental trip with not more than two stops for refueling. All recent big passenger-airplanes are designed for continuous flights of 600 to 800 miles, and their use will, declares Mr. Hanshue, pave the way for lowering transportation rates.

Most of the operator's problems of ground facilities, personnel, purchase of airplanes, and the factors of depreciation and obsolescence are nearing solution. Aircraft construction is rapidly becoming standardized, and in a few years the costs will be substantially reduced and the perils of depreciation and obsolescence greatly lessened. Even under existing conditions, when the cost of air travel is balanced against time saved, the airplane is an economical transport vehicle.

Transportation's Urgent Needs Analyzed

(*Continued from p. 580*)

worthy of the traffic, and this certainly seems to be the case. Common-carrier legislation also has been passed. Private-contract and common carriers more or less overlap as classes, but at the same time are quite different. The legislation involved is not as simple as that relating to motorcoaches. All licensees must take out insurance to protect the shipper, as in the case of steam and electric-railway operators. Reasonable control is the objective sought, it being felt that this assists the franchise holders themselves, operations by freight carriers not needed not being encouraged. The attempt is to protect the small operator from too much competition.

Social Improvement

Additional improved highways mean more motor-car traffic. This is a revolutionary modern development in town and city that is not generally appreciated, as applying to the rural sections particularly. Good roads cleared of snow in winter make all the difference in the world in the social and economic life of the farmer and his family, giving them a motor-vehicle range of 30 or 40 miles instead of that of sleigh travel of former days. Country isolation is being eliminated.

This improved social condition is in a more advanced state of development on the continent of North America than in any other part of the world. Canada, with small population and great road-mileage, is second to only the United States in the use of motorcars.

Prendergast Dissertation

Frank Prendergast, of the Imperial Oil Co., entertained the dinner guests in high degree by dry remarks on the current financial situation and many other topics. He said that recently everybody had pawned their financial parachutes, with dire results to many; but that all should gather the colors of hope and again acquire the aureole of success.

Among other honored guests were:

W. A. Coad, production manager, General Motors of Canada;

W. E. Davis, assistant general manager, General Motors of Canada;

Dr. P. E. Doolittle, president, Canadian Automobile Association;

D. W. Harvey, general manager, Toronto Transportation Commission;

C. A. Jones, general manager, Seiberling Tire & Rubber Co., Ltd.;

R. D. Kerby, president, Canadian Automobile Manufacturers and Export Association, and Durant Motors of Canada, Ltd.;

R. A. Stapelle, past-president, Ontario Motors League;

George Wilson, Commissioner of Finance.

Maintenance and Service Topics

Oil Company's Methods Told and Engineering and Service Departments' Relationship Considered

THE secret of any properly functioning maintenance program consists of systematic, periodic and thorough coverage of a fleet; in the words of the old adage, "A stitch in time saves nine."

J. G. Moxey, of the Atlantic Refining Co., explained at Friday morning's Maintenance Session that such systematic and thorough coverage is obtained in the organization he represents by the use of a questionnaire, containing 69 questions covering the entire motor-vehicle. These questions were framed in such a way that a "Yes" answer is not necessarily a positive answer to the question. The list requires a careful reading on the part of the inspector, and the system of reporting calls for signatures by the inspector and the driver in charge, a copy to the district office and a copy to the central control office, notifying all parties that certain conditions on a particular vehicle need attention. The inspector is further required to fill out within four weeks a correction report consisting of a defective-condition blank, the correction applied, notation and date. Thus, between the two, a full coverage of each machine is received at least five times a year.

The field inspection organization is a function of the field marketing district, looking to the home control office for standardization and control. The responsibility of the field inspector to the chauffeur is cooperation with the chauffeur toward the proper maintenance of his vehicle, and the chauffeur is expected to reciprocate. For example, the chauffeur gives the inspector a list of the parts required for the proper maintenance of his machine, as shown in the initial inspection report, but the chauffeur in no case, except in extreme emergencies, is permitted to order parts himself. He places his request through the field office. He is expected, however, to properly maintain his machine, fill the crankcase, radiator, and so forth, and render a routine report which says, "My truck is in good condition, except as follows ——." He signs this and sends it to the manager, and the manager signs it and sends it on to the head office. Such a report serves as a check against the inspector and his work.

District inspectors hold periodical meetings at which various questions are discussed, and the information is afterward circulated among the men.

Control System Simplifies the Work

By a system of executive control and standardization methods, all the work of operative maintenance is simplified. A motor-truck committee consisting of men from the stockroom, shop and the vehicles meets every month.

Parts departments are maintained at logical centers, and service repairs are made from these shop districts; a main marketing district being divided into three or four individual shop districts, each of these smaller shop districts being an absolutely self-supporting unit.

In connection with operative maintenance, it is also the policy of this corporation to limit the chauffeur so that he shall not touch the under side of the engine or the inside of the transmission, differential or magneto, with the exception of the breaker box. He is permitted to go into these points only upon direct instructions from the inspector in charge. For example, if a bearing is burnt out and the chauffeur happens to be from 75 to 80 miles from home, he telephones in and informs the inspector as to the trouble. The chauffeur will then be instructed by the inspector to drop the crankcase, find out which bearing has failed and get everything ready. In the meantime, the inspector is on his way with the necessary parts, which he installs.

Money Saved on Parts Stock

Overhaul schedules set up by the inspector covering the territory are made up about every six months. They are arrived at by the chief inspector, acting on the general advice of 14 or 15 inspectors directly in touch with the field. Control of the maintenance of a vehicle is thus arrived at about every

six months and the head office is enabled to maintain the necessary parts inventory. It is commonly accepted that the unit-replacement plan in a complete maintenance under general conditions is the best type. With trucks definitely assigned to specific classes of work, predictions and surveys approach almost perfect realization. Shops as well as parts depots are located approximately in the center of vehicle distribution. Shops are run at no profit to the corporation. Stock records are based on the perpetual-inventory method.

When a part goes out through the system, the record immediately goes to the home office so that, by controlling the maximum and minimum allowances on that particular part, the supply can be definitely maintained. Much has been done by a careful study of this inventory, and Mr. Moxey stated that in one instance stock valued at $500,000 had been reduced to $66,000 or from $1,400 to $125 per vehicle, and further reduction seems possible.

Discussing the problem of painting, the speaker stated that, instead of bringing the truck in to the shop, the painter goes to the truck. By installing painting depots throughout the territory, the complete finishing, including decalcomaning, striping, and the like, of four or five machines per week can be completed.

Factors of Economical Truck Life

Mr. Moxey made the statement, in connection with retirement, that he believes the economical life of the motorvehicle, when properly maintained, is indefinite. Retirement of a vehicle in his opinion can be brought about by only three reasons: (*a*) obsolescence, (*b*) inability to properly perform the work assigned, and (*c*) the high cost of the specific type when applied to a particular operating problem.

Mr. Moxey also touched on the subjects of brake-linings and tire maintenance, warned against the policy of reciprocity buying, emphasized the need for a clear statement in sales literature of the advantages of new vehicles, and concluded his paper by the statement that, in his opinion, preventative maintenance by his corporation consists basically of saving the money before it was spent.

In the discussion which followed, H. V. Middleworth, of the Consolidated Gas Co., of New York City, asked what had been done in the check-up on chauffeurs and inspectors, relating that in some instances they had been known to conspire to make overtime pay. Mr. Moxey replied that the Atlantic Refining Co. pays no overtime, the chauffeur and mechanic never get together, and that the shops are run as maintenance and repair shops and not as service depots. During the further discussion the problem of the manufacturers' delivery of parts versus their procurement by the user was considered at length.

A. W. Kinnerson, of the Standard Oil Co. of Ohio; A. J. Scaife, of the White Motor Co.; H. B. Hewitt, of Mitten Management, Inc.; Pierre Schon, of the General Motors Truck Co.; B. H. Eaton, of the Bell Telephone Co. of Pittsburgh; and H. C. Marble, of the White Motor Co. also took part in the discussion, which included the items of budgeting, tire maintenance, depreciation and obsolescence.

Relationship of Engineering and Service

In his paper, E. D. Sirrine, of the Borden's Farm Products Co., placed clearly before the meeting the vital problem of the education of the engineering and service departments with respect to each other's work. He emphasized the salutary effect that this would have upon both the manufacturer and the consumer, and pointed out that each department can learn much from the other and that theory and practice can be made operative only by the fullest appreciation of the other's problems. His paper, which was enthusiastically received, is printed in this number of THE JOURNAL, beginning on page 630.

In the discussion which followed, George P. Anderson, of the Chrysler Corp., expressed his appreciation of the excellence and completeness of the presentation and said that the general breadth of view should make the frank advice given of value to all concerned. He added that his contacts with the technical operator of vehicles had enabled him to learn much and convinced him that poor use was being made of the mine of practical information which this man possessed; he hoped that engineers generally would take the advice to heart.

Sales and Service Men Study Designs

Pierre Schon, of the General Motors Truck Co., announced that, as a result of hearing the paper, he had decided to call a dinner party for his engineering and service departments and read Mr. Sirrine's pronouncement to them. He stated that it has become the policy of the company to charge back to the designing departments items of expense incurred arising from defective design, and that this policy of compelling the engineering department to follow through to the ultimate consumer has been of great disciplinary value. By meetings held between the engineers and the service and sales engineering departments while the designs were still on the drafting board, it has secured the cooperation which has brought good results, and any antagonistic feeling existing between the several departments had soon been dissipated.

A. W. Kinnerson, of the Standard Oil Co. of Ohio, urged a more careful consideration of the service man, pointing out that he is virtually "in a hospital ward; everything inside is down and out, the wire is red hot with requests for service, and so on." Further, his viewpoint is likely to be distorted, and allowances should be made accordingly. Mr. Kinnerson believes, however, that a proper recognition of the service man's position and knowledge will do much to help neutralize his distorted view and result in a great improvement between the two departments.

At this point Chairman F. K. Glynn announced that word had just been received that Mrs. Preble was dangerously ill, and said that he felt that the meeting should send a sympathetic telegram to Mr. Preble, who was to have been Chairman of the two Maintenance Sessions, expressing regret at his inability to be present and impressing him with the members' sincere concern for his family welfare. A motion was made, seconded and carried that such a telegram be sent. The Canadian Section also transmitted its sympathy and sent a suitable gift of flowers to Mrs. Preble.

Garage Design and Vehicle Overhaul

Papers on Fleet Storage Facilities, Maintenance and Carbon Deposits Presented

THREE papers were given at the second session on maintenance on Friday afternoon, supplemented with a short illustrated talk following the first paper. Owing to the absence of Albert Kahn, his paper on Garage and Shop Design was read by Mr. Lewis.

Mr. Kahn's paper, which covers in valuable detail the essential specifications of a modern commercial garage and maintenance shop, with special reference to the type required for fleets of motorcoaches, will be published in a future issue of THE JOURNAL, together with the discussion, supplemented with a written contribution by F. K. Glynn, of the American Telephone & Telegraph Co.

Following this paper, Sidney R. Dresser, of the Kent Garage Co., gave

SPEAKERS AND AUTHORS OF PAPERS PRESENTED AT THE TWO MAINTENANCE SESSIONS

(1) J. D. Moxey, Who Described the Fleet Maintenance System of the Atlantic Refining Co.; (2) Alfred Kahn, Who Wrote the Paper on Modern Garage and Shop Design, Which Was Read by Mr. Lewis; (3) C. J. Livingstone; (4) S. P. Marley and (5) E. C. Martin, Co-Authors of a Paper on Carbon Deposits with Heavy-Duty Engines, Which Mr. Marley Presented

a description, well illustrated by motion pictures, of the company's 41st Street unit in New York City, a 25-story building devoted exclusively to the garaging of cars.

Production Methods Applied to Maintenance

Chairman F. K. Glynn surrendered the chair at this stage to A. J. Scaife, who announced H. B. Hewitt, of the Philadelphia Rural Transit Co., as the next speaker.

Mr. Hewitt described in detail the maintenance methods employed by the Transit company and showed the application of a number of production methods to the work. The paper was illustrated with slides of photographs and charts, including views of the interior of the garage, maintenance shops, pits, test laboratories, electric-welding and other production machines; the methods of handling taxicabs and coaches and doing repair work, remodeling, reconditioning, and so forth. Mr. Hewitt stated that he regards maintenance as a part of automotive production. As such, it necessarily follows original manufacture and is destined to adopt production standards.

In the passenger-car field, the acceptance of new and better vehicles has always been augmented by the lack of good maintenance. The motor-vehicle mortality rate per mile of use has been higher in the past than it probably will be in the future. There were approximately 135 makes of passenger-car in 1914 and only 45 in 1929, with a corresponding reduction in the number of models during the same period. The production of passenger-cars in 1914 was approximately one-half million; in 1928, approximately four million. The change from a large number of manufacturers producing small quantities to a small number producing large quantities is a result of the adoption of American standards of production of a commodity in relatively large demand. The centralization of standardized efforts to produce one essential com-

posite article has resulted in the rapid development of the product, a high degree of efficiency and economic stability of the industry.

Must Increase Efficiency and Economy

There are approximately 100,000 service stations or repair shops in the United States, one for every 250 cars, said Mr. Hewitt. The financial volume of maintenance is now greater than the volume of new-car sales, so that in one respect maintenance is in competition with manufacture. It may be regarded as a cooperative competition, however, for without adequate maintenance the motor-vehicle would lose much of its economic value. Thus, to follow production standards, a maintenance business must centralize its efforts and improve its protective efficiency and economy, as has been done in the manufacture of motor-vehicles.

Mr. Hewitt believes that this does not call for a reduction in the number of outlets, as was the case in the manufacturing field, but for an increase in the volume of business and a corresponding increase in the size of service stations. The increase in volume of better maintenance business is potential. The increase in size of service stations is contingent on executive foresight to adopt production standards, with the result that small shops cannot exist. The maintenance business would thus establish itself on a fundamentally sound basis and add stability to the automotive industry as a whole.

Constructive Maintenance Applied

Mr. Hewitt covered in detail the problem of the application of production standards to the maintenance of the motor-vehicles of the company with which he is connected. He also touched upon constructive maintenance, which he defined as that which effects a radical improvement in design. Many changes of this kind have been found necessary to meet the change in service demands after the equipment was purchased. In many cases there is a resultant better operation and better equipment after five years' service than when the vehicles were new.

Some notable improvements of this type consist of the installation of pneumatic tires on double-deck motor-coaches. This involved a change in wheel-housing and in seating arrangements. Enclosure of upper-deck roofs has substantially increased the revenue, particularly during cold and damp weather. Elimination of a rear door, except for emergency use, and the adoption of one-man operation, represent a saving in operative labor of almost 50 per cent. Changes have been made in the engine to increase the power, decrease fuel and oil consumption, improve reliability, and particularly to reduce carbon monoxide. Such a remodeled coach, as it comes out from the shop, is not a repaired vehicle but one that has been remanufactured on a production basis to compete with new vehicles of the latest standards. It is not a case of doing maintenance only to satisfy operating demand, but of how much can be invested to obtain greater return by prolonging vehicle life. Such a progressive aspect toward maintenance has, according to Mr. Hewitt, doubled the economic life.

If constructive maintenance is to be carried on in the modern manner, asserted Mr. Hewitt, the following are essential:

An engineering department, a drafting department, a test laboratory, suitable labor set-ups, adequate compensation, the use of production-shop methods and tools, suitable testing, inspection, and adequate special equipment such as electric spot-welders, washing machines, electric-arc welders, oxy-acetylene welding equipment, crank-shaft grinders, sheet-metal-working machines, wood-working machines, Brinell testing-machines, scleroscopes, specially designed universal hoisting machines, lifting trucks, power-cleaning equipment, electric screw-drivers, wrenches, exhaust-analyzing equipment, paint-spraying apparatus and numerous other utilities of the production shop and laboratory.

A. L. Clayden, of the Sun Oil Co., next assumed the chair and S. P. Marley, of the Mellon Institute of Industrial Research, read the paper on Carbon Deposits with Heavy-Duty Engines, by C. J. Livingstone, E. C. Martin and himself, which was published in the November issue of the S. A. E. JOURNAL, p. 489.

Miami Aeronautic Meeting in January

THE MIAMI Aeronautic Meeting of the Society will be held at the Miami Biltmore Hotel, Miami, Fla., on Jan. 14. This meeting, which will consist of a single evening session on air transportation, will be held at the time of the Miami Air Meet, which is scheduled for Jan. 13, 14 and 15.

International air-transport between North America and the Latin American countries is productive of numerous engineering problems of a nature not encountered in northern climates. Heat, moisture and salt water combine to promote corrosion of structures and difficulties of engine operation not experienced in the North. Some phases of this situation will be covered by J. M. Eaton, general traffic manager of Pan-American Airways, Inc., whose airlines honeycomb the northern part of South America and maintain air transportation between this Country and the South American republics.

In international air transportation numerous problems of both a legal and operating nature arise, particularly with reference to airports and personnel. These problems will be the subject of discussion following the paper by Major Clarence M. Young, Assistant Secretary of Commerce for Aeronautics, on Problems of International Flying.

Air passenger transportation and aviation of the future will be the general subject of a talk by William B. Stout.

The authors and titles of the papers to be given are as follows:

Air Transportation with the Latin Americas—J. M. Eaton, General Traffic Manager, Pan-American Airways, Inc.

Problems of International Flying—Major Clarence M. Young, Assistant Secretary of Commerce for Aeronautics.

Air Passenger Transportation of the Future—William B. Stout.

Section Visit to Engine Plant

Tour of Hall-Scott Factory Made by Northern Californians—Papers on Five Topics Given

THE FIRST of the meetings of the current season sponsored by the East Bay Division of the Northern California Section was held at the plant of the Hall-Scott Motor Car Co., Berkeley, Calif., on Nov. 14. In the afternoon approximately 100 Section members and their guests made an inspection tour of the factory and after dinner in the cafeteria, which was attended by 125, representatives of the sales, engineering, metallurgical, inspection and service departments of the Company outlined the procedure involved in the design, production, material control, inspection and servicing of a new six-cylinder motorcoach engine. The speakers were Carl Abell, sales engineer, whose topic was The Problem of Building an Engine To Meet a Specific Requirement; C. G. Patch, assistant director of engineering, who told how the answer to the problem was obtained; P. P. Mapes, metallurgist, whose topic was How We Know That We Get What We Want; Alan Freeborn, chief inspector, who outlined briefly the inspection procedure from the time the raw material is received in the plant until the finished engine leaves in a crate; and Carl W. Barnes, general service manager, who described what happens after the engine goes into the hands of the operators.

The Problem and Its Solution

Evolution in the motorcoach industry, said Mr. Abell, was responsible for redesigning the engine. As originally built, the engine developed 75 hp. and was intended for use on vehicles weighing approximately 12,000 lb. and generally operated at 35 m.p.h. The vehicle weight has now increased to from 17,000 to 19,000 lb. and the schedule speed, as a result of keen competition, now ranges from 45 to in some cases 60 m.p.h. The problem was to secure more power without exceeding the limitations of size and weight. In securing increased power, certain major changes that prevented interchangeability with previous engines were incorporated, so the quickest way was to redesign the engine with a new factor of safety to provide for possible future developments that might result in a still greater increase in power.

The four factors utilized in solving the problem of obtaining a greater power output were described by C. G. Patch, the next speaker. These were: higher compression, better volumetric efficiency, higher speeds and increased torque. Volumetric efficiency was improved by putting the intake manifold on the intake side of the head and making the manifold a separate casting that was accessible at all points and could be smoothed on the inside to provide good fuel-distribution. The greater volumetric efficiency resulted in an increased torque so that 332 lb. was obtained at 1250 r.p.m. in the new engine as compared with 292 lb. at 900 r.p.m. in the earlier design. Removing the governor and counterbalancing the crankshaft to reduce the bearing load enables the normal operating-speed to be increased to within the range of the average gearset in a motorcoach and the average running conditions, thus permitting the operator to run the engine as fast as he deems necessary to maintain his schedule speed.

Changes in Construction

Changes in construction of the new engine include an increased height in the upper crankcase to provide for the use of a longer piston, making the lower crankcase in two pieces and providing three large hand-plates to afford ready access to the main sump. To assure clean oil, the suction tube is extended below the screen. With the exception of increasing the oil-pump capacity, no other changes were made in the oil-circulation system. A slightly longer skirt is used on the cylinder-block to allow for a corresponding increase in the piston skirt and the height of the cylinder-head has been increased to provide more water-jacket space. The number of spark-plugs has been changed from 6 to 12.

Adding counterweights and thus reducing the bearing loads approximately 30 per cent is the only change in the crankshaft. A copper-lead alloy is used for the main bearings, which have been made slightly thicker. The piston, made of aluminum alloy, has been increased in height to provide longer life and greater bearing area. It is of the split-skirt type with slots above. Two scrapers of what is known as the compensating type with a small jagged edge are carried above the wristpin. These serve as oil scrapers and also act partly as compression rings. The upper three rings are compression rings and the lower one is a 3/16-in. compensating ring. The oil-filter now has two units instead of one, and if for any reason one becomes clogged, a bypass valve can be opened and the oil circulation will continue.

The intake manifold extends across three cylinders and has a zigzag groove cut approximately in the middle to equalize the vacuum in the two halves. The cylinders are fed by two passages at each side. One of these passages feeds an end cylinder and the other feeds the cylinder at the opposite end, the center cylinders being fed in approximately equal proportion from the two passages. Water-jacketing the intake manifold has been found to warm the gas satisfactorily. The water comes up from the cylinder-block into the manifold and is drawn into the suction side of the water-pump, the circulation being thermostatically controlled at an intake temperature of approximately 123 deg. fahr.

Specifying and Checking the Material

The Company's metallurgist, P. P. Mapes, was the third speaker. He said that virtually all the steel used in the engine was ordered to conform to the various S. A. E. Steel Specifications. After this steel is received at the plant, it is checked for chemical analysis and physical properties, the tests applied depending to a great extent on for what part the material is to be used. In some instances a complete chemical analysis is made, and in addition prints for sulphur segregation and grain flow are sometimes made. The material is heat-treated and subjected to the Brinell, Rockwell or scleroscope test for hardness. The first is used whenever possible on parts that are to be heat-treated but in case the Brinell mark would leave a bad effect on the steel, one of the other two tests is used. The scleroscope test is used on practically all case-hardened parts and the depth of the case is checked by the Rockwell test.

All production tags are routed through the metallurgical department to give a check on the material or for the assigning of the material to a particular job. Records are also kept in that department giving a history of each forging or the stock used in making the various parts.

Forgings as received at the plant are either normalized and rough-machined or normalized and given a heat-treatment for good machining. After being rough-machined they are annealed and then finish-machined and hardened to give certain physical properties.

Work in the Inspection Department

From raw material to the crated engine in the freight car, the inspection department is present at all stages, said Alan Freeborn, the chief inspector,

who presented the fourth paper. Upon their arrival at the plant, castings are examined for general appearance and visible defects and one piece from each lot is checked for conformity to the dimensions given on the blueprints. From here the castings go to the machine-shop and progress from one operation to another until completion, the production and inspection departments working in conjunction at all times.

Except for heat-treatment, forgings are handled in much the same way as castings. When heat-treated forgings are purchased, they are given a general inspection and a check for hardness, usually with the Brinell test. In the shop the forgings are inspected at various points for general appearance, finish and sizes and are then given a final inspection unless a further heat-treatment is necessary. In these cases the forgings are inspected for size, to see that sufficient stock has been left for all tool marks to be removed in grinding wherever that is necessary, and then they are heat-treated. After heat-treatment the parts are inspected for hardness, flaws and in some cases for tensile strength, parts requiring grinding then going to the grinding room.

All parts are checked before assembly. Ordinary go and no-go snap gages are used together with micrometers for outside diameters, while for finer checks micrometers measuring accurately 0.0001 in. and amplifiers giving a direct gage-reading to the same dimension are used, with Johannsen gage blocks that are accurate to 0.00008 in. for even closer work. For inside dimensions go and no-go gages and expanding gages that are accurate to 0.0001 in. are used and special dial-gages reading to 0.002 in. are built into a tool used for cylinder-blocks and other set dimensions. After passing final parts-inspection, all work is sent to the stockroom, from which it is drawn by the sub-assembly department and built into the various sub-assemblies making up a complete engine. The various sub-assemblies go to the final assembly, after which all essential details are checked by an inspector.

The engine is then placed on a stand and run in under its own power, the first 4 hr. being at 600 r.p.m. without load, and the test continues for 24 hr. with gradual increases in speed until 1200 r.p.m. is reached and 35 hp. is being developed. At the end of this run the engine is dismantled and washed thoroughly, the various parts being checked and adjusted. The engine then is given a final run at 1800 r.p.m. During this run oil pressure is checked as well as the water temperature and the general condition of the engine. After being cleaned up and receiving a coat of paint, the engine is crated and shipped.

The last speaker, Carl W. Barnes, general service manager, said that, in addition to supplying replacement parts, the work of the service department is to keep the owner contented, its chief problem being to show operators how to maintain their equipment in good condition. Systematic maintenance on a mileage basis is the orderly and organized conduct of lubrication inspection of wearing parts and replacement of worn parts according to a predetermined schedule, detecting and, if possible, correcting failures before they actually occur, and repairing the damage to associated parts which ordinarily accompanies failure of a stressed part while in service.

Particular emphasis was laid upon the importance of correct and thorough lubrication. The men who handle lubrication play an important rôle in this system of maintenance, so they must not only know how the lubrication should be done but must be competent to make daily inspections of various minor chassis parts, checking up for excessive play and signs of wear and fractures.

Any vehicle can be maintained satisfactorily under the plan as outlined, said Mr. Barnes, with achievement of the maximum benefits depending directly upon the man who is responsible for the engineering design. Regularly recurring maintenance operations should come in groups to prevent tearing down a specific mechanism one month for attention to some wearing part and repeating the operation the following month for another. He recommended that this principle be followed throughout the design of the vehicle, building up the strength or specifications of the weaker parts to carry them over a satisfactorily long period and then make a group job of the whole series of parts. While friction cannot be overcome or wear that eventually requires new parts prevented, knowledge of the causes of the failure of parts will enable the product to be improved. The work of the service department is also an educational job of showing and explaining to operators the benefits to be gained from systematic maintenance, the training of drivers and shop mechanics and the use of recommended replacement parts.

On account of the length of time required for the presentation of the papers, the discussion was confined to a description of the motorcoach maintenance routine of the Key System Transit Co. This was given by W. S. Penfield, superintendent of the motorcoach division, who supplemented his remarks with lantern slides illustrating the various forms used.

Plans for Future Meetings

Edward H. Zeitfuchs, chairman of the Program Committee, announced that the next meeting would be a stag party for members only. This will be held at the Engineers' Club in San Francisco on Dec. 12, and has for its object the fostering of a better acquaintance among the members of the Section.

Other plans, which are more or less tentative at this time, include two more meetings on the east side of San Francisco Bay. One will probably be held in February, the other in late spring.

Lubricants and Fuels Studied

Cleveland Section Glimpses the Oil Business and Stages Antiknock Tests

A GENERAL elementary survey of the oil business was made by Frank Jay Phillippbar, chief chemist of the Kendall Refining Co., in terms easily understood by the layman, at the meeting of the Cleveland Section held Nov. 13 in the ballroom of the Hotel Cleveland. His paper entitled, The A B C's of the Oil Business, was presented to an audience of 115 members and guests at the technical session. W. E. England, Chairman of the Section, presided following the dinner and entertainment. The Standard Oil Co. provided a special high-compression Delco testing-engine so that it could be operated on various fuels that are on sale in Cleveland and their knock and power characteristics determined.

Description of the Oil Business

Mr. Phillippbar outlined the composition of the various grades of crudes and their classification, quoted the United States Government specifications for the initial boiling-points, referred to the Engler distillation method and commented thereon. He referred also to the correlation between the Engler distillation and the air-fuel mixture vaporization-method illustrating with examples the chart devised by Dr. Oscar C.

December Section Meetings Forecast

MEMBERS of the Society visiting cities away from home always are welcome at any Section meeting occurring in the city they are visiting. They will find themselves right at home in a congenial atmosphere and among kindred spirits at any Section meeting in the Country. When contemplating a trip or when on the road, a good plan is to consult the Meetings Calendar in the latest number of the S.A.E. JOURNAL and make memoranda of the dates and places of Section meetings to be held at the time one is to be in such cities. Sometimes the non-resident in a town may miss a very interesting and informative Section meeting by unawareness of the date and place.

Principal features of some of the Section meetings to be held this month are as follows:

Buffalo Section—Dec. 3, Statler Hotel, 8 p. m. George Autenreith, assistant professor of machine design, and Harry Baum, associate professor of electrical engineering, of the College of the City of New York, are to give a paper on Pre-Manifold Vaporization. Both men have been doing research work on various types of vaporizer to handle heavy fuels in gasoline-type engines.

The Buffalo Gasoline Engine Co. has in its test room an engine fitted with the Godward gas generator which has been operating continuously for many weeks on furnace oils, kerosene and light fuel-oils with excellent results. W. E. John, of the company and Secretary of the Buffalo Section, hopes to give the members an opportunity to see this engine in operation on the afternoon of Dec. 3.

Dayton Section—Dec. 18, Engineers Club of Dayton. E. F. Rossman and Walter F. Whitman, of the Delco Products Co., are to present a paper on Riding-Qualities and Shock-Absorbers. The authors are regarded as authorities on the design, application and effects of shock-absorbers. Mr. Rossman is expected to present an impartial analytical and informative discussion of shock-absorbers as a means of improving the riding-qualities of motor-vehicles, and lantern slides and samples of various types of this device will supplement the paper.

Detroit Section—Dec. 9, Book-Cadillac Hotel. This is the only meeting scheduled for this month by the Section. A talk on the Commercial Instinct in Automobile Engineering is to be given by H. S. Vance, of the Studebaker Corp. The title and the speaker indicate that no one who can avoid doing so should miss this address on a highly important phase of design engineering.

Indiana Section—Dec. 12, Hotel Severin, Indianapolis. Riding comfort is the subject that is to be considered from various angles. A member of the faculty of Purdue University is to give a paper on The Engineering Problems of Producing Riding Comfort. Following this a short paper or informal talk on springs, as they relate to ease of riding, will be presented. Two or three talks on shock-absorbers as they affect riding-qualities are also to be given.

Milwaukee Section—Dec. 4, Milwaukee Athletic Club; dinner at 6:30 p. m. The Nitriding of Steels is the subject to be treated in a paper to be presented by R. Sergeson, of the metallurgical department of the Central Alloy Steel Corp., of Massillon, Ohio. The address is to be illustrated with lantern slides. Chairman Paul W. Eells of the Meetings and Papers Committee of the Section, anticipates that this paper on the new steel-treating process will create a great deal of interest and that an excellent meeting will result.

New England Section—Dec. 11, Kenmore Hotel; dinner at 6:30 p. m. The very timely subject of Front-Wheel Drives is to be covered in a disinterested and unbiased way by P. M. Heldt, engineering editor of *Automotive Industries*, and illustrated copiously with slides of current American and European construction details. Automotive engineers everywhere and the motoring public are keenly interested in the application of front drive to private automobiles and are considering the advantages claimed.

Bridgeman and which was shown in the April, 1928, issue of the S.A.E. JOURNAL on p. 445.

The speaker mentioned the sources from which the bulk of motor fuel is obtained, namely, crude oil producing straight-run gasoline, the cracking process, and natural gas, commenting thereon with regard to the processes employed. In conclusion, he discussed lubrication, oil viscosity and fluid friction.

Outline of the Discussion

Discussion centered on the statistics relative to the production of crudes from various fields and on the grades of fuel which produce the least carbon deposition, easiest starting from cold and the like. The respective merits of crude oils having high and those having low flash-points were stated.

In reply to a question, Mr. Phillippbar answered that the carbon-residue tests of an oil afford a good indication of its cleanness, but too great reliance should not be placed on this test as an indication of the amount of carbon that will be deposited. A description was given by H. E. Cottrell, of the Ethyl Gasoline Corp., of the development of antiknock fuels.

Demonstration of Antiknock Tests

Chairman England, before the demonstration was begun, announced that 29 samples of fuel would be tested and the demonstration would be conducted by M. S. Marsh, of the Ethyl Gasoline Corp. Mr. Marsh said that the engine was one used for demonstrating his company's products to various dealer and other organizations. The compression ratio was stated to be slightly higher than 6 to 1. He said that the samples would be tested by number, without any knowledge on his part of the particular name or grade of the fuel. As the tests to determine the antiknock values of the samples proceeded, Mr. Marsh explained the details of the methods he employed and directed attention to the various phases of the tests. Following the demonstration, Mr. Marsh answered a number of questions.

S. A. E. Club of Colorado Meetings

WITH the election of officers for the present meetings year, the S.A.E. Club of Colorado began its active season on Sept. 24. The new Chairman is Fred Ross Eberhardt, of Denver, and the new Secretary and Treasurer is Elmer J. Graham, superintendent of the transportation department of the Public Service Co. of Colorado, also of Denver.

At this first meeting Roland S. Trott presented a paper on front-wheel drives, which brought out discussion on many points. The evening proved to be so interesting that all who attended were eager to have the monthly meetings continue. A second meeting was therefore held in October at the Adams Hotel and was well attended. Orlie Trentham, of the Linde Air Products Co., presented an informative paper on oxy-acetylene welding, and H. K.

Schmick, of the same company, answered all questions propounded by the members. A considerable part of Mr. Trentham's paper is published in this number of the S.A.E. JOURNAL, in Production Engineering. The October meeting was pronounced a huge success.

The third meeting was scheduled for Nov. 22 with a talk on tractor operation, illustrated with motion pictures, to be given by Mr. Held, of Clinton & Held, representatives of the Caterpillar Tractor Co. in the Denver territory.

In December, on either the 10th or the 17th, A. M. Hall will give a talk before the Club on Crankless Engines and is to show a small model of such an engine. A subsequent meeting is expected to be devoted to the Diesel engine.

The officers desire to get into communication with men who may be expecting to visit or pass through Denver later in the winter and would be willing to give authoritative talks on any subject related in any way to the automotive industry. Also, the Club extends an invitation to members of the Society when in or passing through the city to attend its future meetings.

Service, a Phase of Efficiency

Cooperation between Factory and Field Forces and Equipment and Car Makers Described at Buffalo

SPEAKING before 100 members and guests of the Buffalo Section at the Statler Hotel on Nov. 5, Fred Wells, service manager of the Pierce-Arrow Motor Car Co., and Elsworth R. Boeck, president of the Truck Equipment Co., discussed service as it relates to the automotive engineer and the service manager.

The former defined service as being any activity that tends to assist the purchaser of an article to derive full benefit from its inherent potential utility. After reviewing briefly the various requirements of service and the different views taken of it, Mr. Wells stated that every member of a manufacturing organization as well as distributors and dealers who have direct contact with the motoring public must recognize the requirements of service, some of which are fundamental and involve the factory organization. In the order of their relative importance these essentials, said Mr. Wells, are design, accessibility, interchangeability, and manufacturing and inspection.

The main function of a manufacturer's service department is to secure greater efficiency and economy of operation for owners through a strong and superior field service organization. Of almost equal importance are fostering the spirit of service in every member of the distributor's and dealer's service organization and gradual improvement of the product in manufacture and design. The first is accomplished by close scrutiny and supervision through district service representatives, who should be qualified to advise and supervise in exceptionally difficult and baffling cases of trouble and repairs and who are held responsible for maintaining a high standard of service.

To secure the best results in the second line of endeavor, dealers, distributors and service representatives should be encouraged to send in their own complaints as well as those made by owners. In this way a complete history of the performance of the product in the field can be secured and information obtained regarding the results following the adoption of certain changes or whether additional changes are necessary.

Service Department an Information Bureau

The factory service department of the company he represents, said Mr. Wells, is a bureau of information for distributors, dealers and owners alike and, in addition to answering questions pertaining to operation and care, adjustment, repairs and replacement, does considerable development work, all of which is intended to better the service rendered the owner. Another feature of its activities is to advance the manufacturers' commercial position by assisting the less active distributors in building up their territories.

The trend toward the maintenance of service stations by specialists and vendors of equipment was commented on briefly. Since the personnel at such stations is trained to handle a particular line of work and the equipment is adapted thereto, greater efficiency and the maximum effectiveness are secured.

Mr. Boeck's paper described how the equipment manufacturer works with the automobile manufacturer to supply tools and equipment for the most expeditious, economical and satisfactory servicing. His remarks were supplemented with numerous lantern slides.

Discussion following the presentation of the papers covered the installation by dealers of facilities for lubricating cars, the training of mechanics, developing special tools and equipment, and cooperation between production and engineering departments.

Functions of a Quality Department

Mr. Nicodemus, assistant vice-president in charge of manufacturing at the Pierce-Arrow plant, described the functions of the recently established quality department. This department not only works on improvements in the manufacturing division but also acts as a clearing house for defects on which reports are received. A man in this department is assigned work on some special line; for example, one group on paint cooperates with the firms supplying this material and with the purchasing department, to see that the right kind of paint is furnished; with the laboratory while the paint is being tested; and with the paint department to see that the material is correctly applied. Other members of this department circulate through the factory watching, among other things, the trimming, cushions and backs and the body construction. As complaints come in either through the service department or from the factory inspection department, a man is assigned to that item to obtain whatever material or operation may be necessary to remedy the defect.

At a brief business session preceding the meeting representatives of the Section on the Nominating and Sections Committees of the Society were chosen. Chairman E. W. Kimball, engineer with the Vacuum Oil Co., was elected to represent the Section on the Nominating Committee, with William Edgar John, of the Buffalo Gasoline Motor Co., as alternate. Elsworth R. Boeck, of the Truck Equipment Co., was chosen as a member of the Sections Committee of the Society.

Four-Speed Transmissions to Remain

FOUR-SPEED transmissions will not only be a permanent feature of automobiles but before many years will be standard construction in most of the moderate-priced vehicles, in the opinion expressed by H. C. McCaslin, resident engineer of Durant Motors of Canada, Ltd., speaking at the monthly meeting of the Canadian Section in the Royal York Hotel in Toronto on Wednesday night, Nov. 20.

The most notable advantages of the four-speed transmission, said Mr. McCaslin, are the lessened wear and tear on the engine, economy of operation, and acceleration in third gear for crowded traffic and hilly country. With the four-speed transmission, having an easy shift between third and fourth speeds, it is possible to gear the rear axle with a ratio of 3.7 or 3.9 instead of 4.4 or 4.8 as is common practice with a standard three-speed transmission. This cuts down the engine speed in high gear, thereby increasing fuel and oil economy; eliminates engine

vibration at ordinary driving speeds; and results in better cooling, more comfort for the occupants and less fatigue for the driver, especially on long trips.

Probably the most pronounced improvement or tendency in 1929 and 1930 models, Mr. McCaslin stated, was the adoption of four-speed transmissions having a noiseless third speed, or three-speed transmissions with noiseless second speeds. The speaker then went on to describe and analyze the various types of gear; namely, internal gears, which remain the predominating type; and herringbone, helical and spur gears. Laboratory tests were described and data given of the low power-loss to show the efficiency of internal gearing. Quietness of operation is also an important advantage of internal gears as compared with spur gears.

Herringbone gears are being used to some extent in Europe and America to obtain a quiet second or third speed, said Mr. McCaslin. The same reason applies to the use of helical gears, although this type is to be found only on some European models, not on American cars. At least one American manufacturer is using a spur gear in a four-speed transmission for a silent third speed.

Two-Speed Axles Being Tried

The two-speed axle is being used to a limited extent with fair success in passenger-cars in Europe to obtain desirable speed changes for traffic and level and hilly roads by changing the final ratio in the axle. This method has also been employed successfully on speed trucks in the United States. The Durant and International Harvester companies are using the two-speed axle on their one-ton trucks with gratifying results, according to the speaker, and other manufacturers are experimenting with this method. Whether this two-speed axle will extend to use in passenger-cars in America remains to be seen. The one objection to this method of obtaining a quiet traffic-speed is the extra gearshift lever that must be used.

In conclusion, Mr. McCaslin said that the disadvantage of four-speed transmissions seems to be limited to the variety in gearshift positions. Several types of shift are on the market, and all seem to be "standard". He believes this difficulty can be overcome by educating the driving public to a one-standard shift position. The same period of transition was passed through with the present three-speed gearshift, although it has not been long since there were three distinct types of shift position on large-production cars. The three-speed positions were standardized by the cooperation of the manufacturers through the Society, and it will be by similar cooperation that the positions of the four-speed gearshift will eventually be standardized.

Chicago Considers Diesel Engines

Three Papers Presented Review History, Recent Developments and Some Automotive Applications

WHEN the regular monthly meeting of the Chicago Section was convened on the evening of Nov. 5 at the Hotel Morrison, 108 members and guests were present to hear the three papers to be given, all dealing with Diesel engines. Secretary John O. Eisinger, who opened the meeting, read a telegram from H. L. Horning, of the Waukesha Motor Co., expressing the latter's regret at his inability to be present. R. E. Plimpton, of the McGraw-Hill Publishing Co., was nominated representative of the Section on the National Nominating Committee, with Benjamin S. Pfeiffer, of the Magee-Pfeiffer Co., as alternate; and A. W. Scarratt, of the International Harvester Co., was elected to represent the Section at the Annual Meeting of the Society.

Mr. Eisinger then relinquished the chair to C. C. Hinkley, of the Buda Co., who, after some introductory remarks, presented the speakers of the evening: H. D. Hill, vice-president and general manager of the Hill-Diesel Engine Co., of Lansing, Mich.; F. P. Gruetzner, of Fairbanks, Morse & Co.; and Howard M. Zoerb, of the Nordberg Mfg. Co., of Milwaukee.

All three speakers dealt with Diesel engines designed for other than normal automotive work; that is, for stationary or marine service.

A Modified Diesel-Cycle System

Mr. Hill described a modified Diesel system, operating on a combination of the constant-volume and constant-pressure cycles. Airless injection of the fuel is used at a time and rate which will permit the completion of the combustion process in the very brief period available in a high-speed engine. This, the speaker stated, means lower compression and maximum pressures somewhat higher than are usual, but not dangerously high, resulting in higher mean effective pressures, higher thermal efficiency and slightly reduced mechanical efficiency.

Small Marine and Generator Engines

Reviewing briefly the history of the Diesel engine and its applications, Mr. Gruetzner's paper described the largest and the smallest units built by the company he represents. The smallest, built in two, three, four and six-cylinder models, has 6-in. bore and 6½-in. stroke. As a marine engine it runs at 650 to 700 r.p.m. and is rated at 25, 35, 45 and 60 b.hp. according to the number of cylinders; for generator service, two, three and four-cylinder plants that run at 800 r.p.m. are used and are rated at 20, 30 and 40 kw. respectively.

"The efficiency of the Diesel cycle," said Mr. Gruetzner, "is among the best known. With a fuel consumption of 0.40 lb. per b.hp-hr., we transform 33 per cent of the total heat into useful work. We have many installations in which 1 kw-hr. is produced under normal operating conditions for one cent or less, taking all charges into account.

The complete heat balance shown in a recent test was said to be as follows:

Absorbed by	Per Cent
Jacket Water	17.28
Piston Cooling	8.37
Useful Work	33.00
Friction, Exhaust and Radiation	41.35

The third speaker, Mr. Zoerb, divided Diesel engines into air-injection and airless-injection types, and showed a number of slides illustrating installations of Nordberg engines.

Observations on German Trucks

The discussion centered, in the main, on questions of technical details. A point of specifically automotive interest was raised by Harte Cooke, of McIntosh & Seymour, of Auburn, N. Y., who made some observations regarding the applications of Diesel engines to vehicles, and said in part:

We very seldom do anything without being forced by economic conditions to do it. For this reason, the development of the Diesel engine for automotive use probably will be more rapid in Europe than in this Country. Over there gasoline costs 50 or 60 cents per gal., while one can buy fuels suitable for use in a Diesel engine at a relatively reasonable price. Makers of trucks in Germany told us that they were compelled by economic forces to build Diesel trucks. I rode on three Diesel-engine trucks in Europe, one being a truck with a Bosch engine and Arco system. While we rode up a hill in Stuttgart, another party followed in a passenger-car to observe the appearance of the exhaust. The truck operated very well in the traffic, and the engine seemed to be as flexible as carbureter-type engines. It worked very nicely ascending the hill. The occupants of the automobile said that the exhaust had been very good at all times. Going down hill, I rode in the automobile and watched the exhaust, which appeared all right.

One 5½-ton truck was put through all sorts of maneuvers, and the Diesel equipment seemed to be just as flexible as the gasoline engine; I couldn't see any difference. The exhaust was perfectly clear.

Today, some European manufacturers are working on Diesel engines for passenger-cars, and I suppose the same is true in this Country. How these attempts will work out depends largely upon economic factors and on how the engineers work out the problem of the cleanliness of the fuel supply.

Power Requirement Favors Diesel Engine

The first automotive Diesel engines operated at approximately 1000 r.p.m. Combustion was gradually improved and the engine speed increased to 1300, 1350 and 1500 r.p.m. I suppose eventually it will go still higher. As the speed is increased, the weight per horsepower, the space required and the cost can be decreased. All these reductions help in automotive work. Some of the latest European automotive engines, for example, an engine of about 80 hp. with six cylinders, weigh about 8 kg. (about 17 lb.) per hp. and run in the neighborhood of 1500 r.p.m.

The tendency on all this equipment is to require more power. In America it is desired that trucks travel at passenger-car speed so that general traffic on the road will be interfered with less. As this requires greater power, it is apparent that the power of truck engines will be increased. Such an increase leads into the power range in which Diesel engines are more suitable than the carbureter type of engine. I assume that will be true also of motorcoaches as these are built bigger and operated on faster schedules.

Factors in Airway Improvement

Detroit Aeronautic Division Told What Is Needed To Create Good Roads for Airplanes

GOOD ROADS for Airplanes was the subject on which Graham B. Grosvenor, president of the Aviation Corp., spoke to the members of the Aeronautic Division of the Detroit Section, who met on Nov. 18.

After reviewing the strides made by aviation during the last dozen years, Mr. Grosvenor dwelt on the element of increased safety in flying when visibility is low, as for example in very dense fog. The principal factors in making possible this accomplishment are a new application of visual radio-beacon, an improved instrument for indicating the longitudinal and lateral attitude of an airplane, a new directional gyroscope and a sensitive barometric altimeter so delicate as to measure the altitude of the airplane within a few feet of the ground. This means, the speaker said, that a principle has been developed which, when eventually perfected for commercial use, will make the airplane more independent of weather conditions than any other form of transportation.

Highway and Airway Expenditures Compared

Mr. Grosvenor compared the present state of and the policy governing American highway systems with the airway situation. Congress approved a system of interstate roadways to be built in 10 years, and in 1923 appropriated $50,000,000 for that purpose. Since then, appropriations have been made every two years. From 1925 to and including 1929, the appropriations have been $75,000,000 per annum.

On the other hand, more than 15,000 miles of lighted and improved airways are now completed or authorized. This means that 15,500 miles will be lighted for night flying and be equipped with weather-reporting facilities, radio communications to planes in the air and radio-beacon service. Congress appropriated in the last fiscal year $5,408,620 for the improvement of airways. It is estimated that the appropriation for the pending year will be about $7,500,000. That is a very small sum compared with the $75,000,000 annually expended by the Federal Government to establish good roads.

States Should Join in Task

The time has arrived, continued Mr. Grosvenor, for individual States to cooperate actively with the Federal Government in the development of efficient airways. Only four States have taken such steps so far. But the mass of people will not take to traveling in the air until flying has become customary and passenger lines are in operation throughout the Country. This cannot be done until a system of airways is established that will allow a passenger airplane in distress, or buffeted by weather conditions, to land in emergency fields placed at sufficiently close intervals to make the riders feel safe.

Of more than 23,000 miles of domestic airways, only 10,183 miles have been lighted, and no Federal, State or county program worthy of the name has been set up for providing intermediate or emergency landing-fields. This must be undertaken and completed before what can be termed ordinary safeguards are thrown around flying.

Estimated Cost of Airway Development

To obtain a clear idea of the cost of airway development, Mr. Grosvenor had a survey made of the line between St. Louis and Denver, a distance of 773 miles, including level, rolling and mountainous terrain. The average flying time over this route is 6 hr. 50 min. The number of intermediate fields required in addition to municipal fields already established along this route would be 68. According to this survey, the cost of such fields would include $1,211,520 for the real estate and proper conditioning of the fields; $290,780.52 for type-D field lighting, representing an average of $3,540.89 for each of the 68 fields; $20,400 for primary connections; $292,320 for 1392 acetylene route-blinkers installed at half-mile intervals; and small-plot leases for the blinkers, at $10 per year, $13,920 annually.

This would bring the total airway estimate for this 773-mile route to $1,777,940.52, or $2,300 per mile without radio cost.

If this estimate can be taken to represent average conditions, a National airway program would call for the expenditure of more than $40,000,000, a not insignificant sum, to provide adequate ground facilities on existing routes. These routes are certain to be extended because ease of expansion is an advantage of the airplane. It does not confine itself to following the line of migration as the railroads have largely done, but brings into closer communication all sections of the Country, the North and South, as well as the East and West.

Aircraft Safety Made Plain

LePage Simplifies Fundamentals at Boston Meeting and Describes Features of Entrants for Safety Contest

BEEFSTEAK was the fare at the Hotel Kenmore in Boston when the New England Section met on Nov. 13 to discuss aeronautic subjects. Following the dinner, Albert Lodge was elected a member of the Sections Committee of the Society and H. A. Moyer was elected to the National Nominating Committee of the Society for 1930.

R. L. O'Brien, who is connected with the aviation branch of the Massachusetts Department of Public Works, spoke briefly of the numerical development of airplanes and their legal control in the State. His work includes oversight of the licensing of airplanes and aviators and the enforcement of the laws. All complaints are investigated, including one from a doctor who said that dangerous flying over his nursery was an annoyance. It was not possible to take action on this because

THE AUTOGIRO AND THE PTERODACTYL AIRPLANES MAKING A DEMONSTRATION FLIGHT

the planes complained of were flying so high that the doctor could not read their numbers, even with a pair of field-glasses.

Boston Airport Developing Well

Capt. A. L. Edson, who is in charge of the municipal airport of Boston, told of the splendid service on the Colonial Air Line between Boston and New York City. A steward hands out maps showing points of interest, serves refreshments and makes explanations to the passengers. Recently he took special pains to point out the altimeter and other instruments of the Ford tri-motor plane to an innocent-looking passenger, explaining the all-metal construction and the fact that the plane could keep on going if one engine failed. Inquiry later disclosed that this passenger was William B. Stout.

A radio-beam station will soon go into operation at the airport and 24-hr. weather service is maintained by four men. Weather reports will be broadcast every half-hour, covering the course between Newark, N. J., and Boston. The port is located beside the harbor, on land leased from the State at $1 per year. The city has invested about $500,000 in improvements, including an administration building costing about $200,000. Enough additional private capital has been invested to bring the total amount to about $2,000,000.

Airplanes Safe and Becoming Safer

Fundamentals of Flight from the Standpoint of Safety was the subject of the paper presented by W. Laurence LePage, president of the Kellett Aircraft Corp., of Philadelphia. Mr. LePage said that a list of equations dealing with the action of a wheel might seem formidable, but the use of the wheel is simple and common. The same applies to the understanding of airplanes, and he proceeded to explain lift, drag, stability and control in simple and easily visualized terms, with the aid of diagrams.

That an airplane is fundamentally a safe vehicle is hardly disputed now. They seldom break up in the air, and any accidents of that sort come to experimental planes. Most accidents are due to errors of judgment on the part of the pilot, and there would be many more highway accidents if as much was left to the judgment of drivers as is put into the hands of the airplane pilot. Problems of safety are being solved, and successful pilots now are setting records of safety that rival those of other forms of transportation. New designs like the tailless Hill pterodactyl and the Cierva Autogiro show promise of a degree of safety greater than the conventional airplane possesses.

Photographs of details of airplanes entered in the Guggenheim Safe Aircraft Competition, taken by Mr. LePage at Mitchell Field, were shown and explained. Mr. LePage concluded his paper with a description of the Autogiro and a simple explanation of its principles and operation, illustrated with diagrams and photographs.

The paper was followed by discussion. One of the points brought out was that it is quite possible to design the Autogiro so that it will have a vertical landing-speed of about 15 ft. per sec. or 10 m.p.h., approximately the velocity attained by an object falling freely through a distance of 4 ft., and no forward motion whatever. Many vertical landings have been made, according to Mr. LePage, with ordinary 30 x 5-in. airplane tires and shock-absorbers giving a vertical travel of 12 in. or a little more, and no tires have burst from this treatment. The Goodyear air wheel is now being used, and it is thought that the shock-absorbers may be eliminated.

A Novel Aeronautic Engine

Earl Describes Compact Engine and Rathert Gives Airplane Study to Northwest Section

PORTLAND was the scene of the meeting of the Northwest Section held on Nov. 2 in the Heathman Hotel. The meeting began at 3 p.m., and included a large aeronautic display held at the hotel and a dinner served at 6.30. One item of interest is that car storage was included by the hotel with the cost of the dinner, which was $1.75. At the beginning of the technical session, the name of each man who had registered was called, and he was asked to stand for an introduction. Chairman Robert S. Taylor spoke of the membership effort that is being made, with the hope that the present Northwest Section, holding meetings alternately in the States of Oregon and Washington, may soon grow into two Sections.

Cylinders Parallel to the Shaft

Aircraft Powerplants was the subject of the paper by H. W. Earl, of the Earl Aircraft Co., who described the reasoning that led to the design of his engine having 18 cylinders parallel to the main shaft. Adapting to airplanes a type of engine that has been developed for automobiles has not produced an ideal powerplant, because the air resistance is excessive. Mr. Earl has been working for more than a decade on another line of approach, that of producing an engine of an ideal aerodynamic shape. He had an experimental model of this engine on exhibition at the meeting, and also illustrations showing its construction.

The Earl engine consists of nine pairs of opposed cylinders arranged in a circle with their axes parallel to the main shaft. The pistons are arranged in pairs at opposite ends of straight connecting-rods, in the center of each of which are two conical rollers that make contact with a four-point cam mounted on the main shaft and giving the piston four complete strokes per revolution of the shaft. Inlet and exhaust are controlled by sleeve valves oscillated by cams mounted directly on the main shaft. Cooling is by water or a fluid that will remain liquid at high temperature; and the radiator surrounds the engine, having an inside diameter of 17½ in. and an outside diameter of 24 in.

One of the distinctive features described by Mr. Earl is an arrangement whereby the charge in each cylinder can be ignited from the preceding cylinder. This does not take the place of electric ignition but is said to make running possible with the electric ignition turned off or after the magneto has ceased to function. Interference with radio operation is thus avoided.

Advantages claimed for the engine are a weight of only 1 lb. per horsepower; low speed for the propeller, which is mounted directly on the main shaft of the engine; low resistance,

because of small diameter; elimination of all babbitt bearings and springs; low cost; the high efficiency of the propeller; the reduction in air resistance; and the reduction, both direct and indirect, in weight, are claimed to make possible the same speed and net load from 300 hp. as from a 400-hp. radial engine.

Mr. Earl's paper was followed by discussion, most of which was questions and answers regarding high-temperature liquid-cooling, and the resistance and cooling capacity of the engine and radiator in the Earl design.

Formula for Comparing Airplanes

Commercial Airplanes as Cargo Carriers is the title of a paper which was read by G. A. Rathert, chief engineer of the Breese Aircraft Corp. of Portland, Ore. In it he has listed the following as the main items determining the merit of an airplane: speed, pay-load, horsepower, structural strength, stability, safety, vision, initial cost and operating cost. Of these, costs may be assumed as roughly proportional to the power, and several of the other factors are considered not to be measurable but must necessarily be made satisfactory. The three remaining factors are combined into a formula for merit rating, which is considered to be the product of the speed in miles per hour and the pay-load in pounds divided by the horsepower.

This merit rating has been computed for more than 200 airplanes and the results combined in two tables. One table shows the pay-load, speed, horsepower, merit rating and other data of the averages of each class; and the second table gives the data for the airplane having the highest merit rating in each class. The planes are divided into four groups according to weight, Group 1 including airplanes from 1200 to 2500 lb., and Group 4 taking in all airplanes exceeding 10,000 lb. in gross weight. Each group is divided into biplanes, externally braced monoplanes, internally braced monoplanes, and sesquiplanes, if examples of all these types are found. The highest development is indicated in the group including airplanes between 2500 and 5000 lb. gross weight. Ratings in the two groups of smaller airplanes are higher than those of the larger planes. The general advantage seems with the monoplane.

Walter R. Jones agreed, in the discussion, that a figure of merit like that given by Mr. Rathert is very desirable, and suggested that it should be based upon the cruising speed of an airplane at normal flying altitude instead of its maximum speed at ground level. The average altitude of flying between San Francisco and Chicago is between 5000 and 10,000 ft. Climbing ability should also be given consideration in deciding definitely upon the merit of a design.

The next meeting of the Section will be held in Seattle on Dec. 14. It is expected that representatives of the Graham-Paige, Packard, Reo and Chrysler companies will be present to give papers on the improved transmissions used in cars made by these companies.

Front Drives Pull Well

Attendance at Milwaukee Section Meeting Reflects Interest in Newly Commercialized Construction

PETER M. HELDT, engineering editor of *Automotive Industries*, was the speaker who drew an attendance of 176 at the front-wheel-drive meeting of the Milwaukee Section of the Society, held at the Milwaukee Athletic Club, Nov. 6. Chairman Arthur C. Wollensak presided at the session, which followed the usual dinner. The reading of Mr. Heldt's paper was followed by lively discussion on the subject, particularly with relation to braking and control.

Reasons for the usual distribution of the functions of the four wheels, before four-wheel braking became common, were given by Mr. Heldt as a starting point. Steering by the front wheels is most convenient; and it seems simpler to apply the propulsion and braking functions to the rear wheels, which are not pivoted. The demand for a lower center of gravity for the vehicle is said to be the real reason for front-wheel drives, in spite of the greater complication and cost that seem to be involved and a slight disadvantage in possible propulsive effort. Designers have been striving for a number of years to lower the center of gravity, and almost every possible expedient to this end that is available with rear-wheel drives has been exhausted.

Diagrams were shown to demonstrate that the normal weight distribution is less favorable to front-wheel than to rear-wheel propulsion, especially when climbing a hill or during acceleration, under which conditions loss of traction is most objectionable. Because of these reasons and the fact that more of the weight of a loaded motor-truck commonly falls on the rear wheels, Mr. Heldt believes that front-wheel driving will be adopted for commercial vehicles only in special cases in which the importance of a low platform is a controlling factor. The objections are not so important in a passenger-car.

Riding and Shimmy Improved

Incidental advantages of the front-wheel drive were given by Mr. Heldt as improved riding-qualities because of the reduction in unsprung weight, and removal of the low point of the chassis from near the middle of its length. Tendency to shimmy is greatly reduced by moving the front brake-drums from the wheels to the sides of the differential, where they are not a part of the unsprung weight of the axle.

Universal-joint problems in connection with front-wheel drives were considered by Mr. Heldt, who said that it is at least very desirable to provide a system of universal-joints that will preserve a uniform velocity-ratio between the differential and the wheel, regardless of spring action and steering angle. Provision has not been made for this in the front drives of four-wheel-drive motor-trucks, according to Mr. Heldt, but the condition has been met in the two front-drive passenger-cars now on the American market.

During and following the delivery of the paper, Mr. Heldt exhibited a number of slides showing the general and detail construction of the two American front-wheel-drive cars and the English patent drawing of the Alvis car which has two four-cylinder engines side by side connected to a central shaft and two swinging half-axles in front.

Meade F. Moore, of the Nash Motors Co., was called upon for his observations at the Paris and London automobile shows. He said he found that a number of European cars have the rear differential mounted on the chassis frame, with individually sprung rear wheels. In some of the four-passenger sport cars, there is a bump in the floor for the propeller-shaft, so that the passengers must place their feet in little boxes on each side. He considers the front-wheel drive to be a better solution of the problem.

Independent Springing Unsightly

Four front-drive cars were seen at the Paris show, and Mr. Moore regarded the one American representative of the class as the best-looking car of the lot. Individual mounting of the wheels and peculiar arrangement of the springs complicate the problem of appearance. The front end of the Bucciali is mounted on a cross spring in front of the radiator, and headlamps are built into a cross tube that rests on the spring. The top of this car comes only to the chin of Mr. Moore, who is not a tall man. No front-drive car was seen at the London show, but Mr. Moore saw the experimental Alvis car, the two engines of which are connected to the drive through herringbone gears, a practice

that he believes would not be acceptable to Americans.

In answer to questions, Mr. Heldt said that the objections to independent springing of the wheels seem to be awkward appearance and an aversion to accepting a car that has no substantial front axle. The large quantities in which cars are produced in this Country make American manufacturers more conservative than European makers about producing a car that may not become popular. He referred to a letter from a German acquaintance who reported building a front-drive car in 1905 and said that there are no basic patents on front-wheel drives but that a designer must watch out for detail patents.

A local representative of one of the manufacturers of the front-drive cars answered a question about performance by saying that the torque at the front axle is 34.8 per cent greater than at the rear, with an engine of the same size and the same gear-ratio. He disclaimed the engineering ability to explain how this comes about, and Mr. Heldt remarked that he is not enough of a salesman to believe that it is necessary to claim everything in the world for a product which has some good features. He believes that the front drive has real advantages but that the torque at the wheels will not be greater unless it results from a difference in engine or gear ratio.

Front Braking and Safety

J. C. Slonneger, of the International Harvester Co., said that his experience and observation showed that front tires now wear faster than rear tires, and he questioned if applying the drive to the front wheels would not aggravate that condition. Accidents at curves are more likely to be caused by some obstruction that is not seen soon enough than by skidding. Mr. Slonneger agreed that the great advantage of front drive is in making a car lower, but he is afraid that braking effect will be sacrificed by shifting more weight to the front, where it cannot be used to full advantage in connection with braking for fear of slipping the front wheels.

Bureau of Standards experiments were referred to by Mr. Heldt, who said that he now believes it is less dangerous to lock the front wheels than to lock the rear ones. H. L. Zimmerman, of the Nash Motors Co., supported Mr. Heldt by reporting tests with experimental cars built with front brakes only and driven through a winter on icy pavements. It had been found impossible to make such a car skid so that it would swing end for end.

Some attention was given to the failure of front-drive cars to win any of the Indianapolis races. A suspicion was voiced that universal-joint failure had occurred because of "gunning" the engines on curves. Secretary Debbink had the impression that most of the failures of front-drive cars on the race track had been due to accessory drives, principally that of the supercharger, and reported an opinion from observers that this resulted from increased slippage of the front wheels because of the transfer of weight to the rear axle during acceleration.

A Double Session at Detroit

Afternoon Technical Session on Nitralloy—Downey Speaks on Car Design in the Evening

THE regular monthly meeting of the Detroit Section was made up of two sessions, or rather three. First came a technical session at 5 p. m., in which Hilton G. Freeland gave a paper on Nitralloy in the Automotive Industry. This was followed by the usual dinner, with entertainers from the Kit Kat Klub. We are told by *The Supercharger* that the names of the entertainers are announced, but not their telephone numbers. After the dinner came the regular monthly session, in which A. C. Downey, general purchasing agent of the Chrysler Corp., gave a talk on Engineering for Economy. The attendance was 50 at the afternoon session, 406 enjoyed the dinner, and 460 members and guests came to hear a purchasing agent talk without saying, No.

Vice-Chairman P. J. Kent introduced Mr. Freeland at the afternoon session with an outline of his extensive metallurgical experience, beginning with the Detroit Testing Laboratory in 1909 and following with the General Motors chemical laboratory, the Hoover Steel Ball Co., and the Ludlum Steel Co., for which he is now sales metallurgist.

Origin and Properties of Nitralloy

Seldom have the wishes of the metallurgist and the requirements of the manufacturer been so nearly realized in any one steel as in nitralloy, according to Mr. Freeland. The problems of its utilization are not fully solved, but enough is known to show that it has great possibilities. The nitriding treatment gives it a surface hardness greater than that of any other steel now used in automobile construction, equivalent to 1000-1200 Brinell as compared with 700 Brinell for carbonized steel. Nevertheless, the core has high physical properties, and the hardened product can be cold-straightened without destroying its fatigue resistance.

Dr. Adolph Fry developed the material because he recognized the need for a steel which would deteriorate as little as possible in hardening and concluded that this could be attained by eliminating high temperatures in the treatment. After it was found that the surface of steel can be hardened by the use of nitrogen, he determined which nitrides are most stable and which alloys are most conducive to penetration. He found that aluminum nitrides resist dissociation up to very high temperatures and that molybdenum eliminates any tendency toward temper brittleness.

Two grades of nitralloy are now in use in the United States, one having a carbon range of 0.20-0.30 and the other a carbon range of 0.30-0.40 per cent.

Nitralloy cannot be classed as a stainless steel, but it resists the attack of ordinary water and that of salt water to a considerable extent. This is true only if the original nitrided surface is not removed except by a little lapping. Nitralloy does not need to be ground after hardening, because the surface is not injured and the only distortion ordinarily is a very slight growth, which can be allowed for in the original machining. Tests have shown that nitrided nitralloy crankshafts can be straightened cold without detrimental effects.

Treating Time Being Reduced

Mr. Freeland described the process of nitriding in some detail and said that experience is showing that long periods of heating in ammonia are not necessary for many kinds of work. The time required now seems to range from 1½ hr. for producing very hard phonograph needles to 30-60 hr. for crankshafts and gears.

Discussion of the paper showed interest in the question of cost. Mr. Freeland said that the present base price of nitralloy is 8 cents per lb. and the expense for ammonia is very slight. Savings are said to result often from the elimination of a grinding operation and the avoidance of losses. It is possible that more extensive use will make the cost much lower, but because of the high aluminum content greater care in production is necessary than is required for ordinary alloy-steels.

Various definite questions regarding heat-treating were answered by Mr. Freeland. He was unable to explain why the removal of a very small amount from the surface should destroy the corrosion resistance of a part

that has been nitrided deeply; it may be due to a concentration of nitrides at the surface. In one case the corrosion resistance of parts that had been nitrided for 90 hr. was destroyed by removing 0.002 in. from the surface.

When Engineer's Talent Is Taxed

After the dinner, the chairman introduced the guests at the head table and then gave a light sketch of Colonel Downey's life, beginning with his father, who was a prominent Indiana lawyer and Treasury official under President Wilson. "Al" Downey was once a major-league baseball player. During the war, he became chief contract officer for the Signal Corps and later for the aviation section.

Colonel Downey said that he had hoped to address the engineers on the relationship between engineers, salesmen and buyers, but found that the engineers had put through a change on him, and the rules require the purchasing agent to follow engineering changes.

No great skill is required for an engineer whose resources are unlimited to design a car of which he can be justly proud; the real test comes when orders are received to design a car that can be sold at a profit within a given price class and be better than other cars in its class. The engineer who tries to create a masterpiece has missed his calling, in Colonel Downey's opinion. He should be an artist or a composer. The real engineer, confronted by a tough assignment, goes into a huddle with the manager and the purchasing agent for assistance.

Style Changes Are an Economic Loss

Frequent engineering changes came in for criticism by the speaker. Some are due to faulty original design, some to troubles in the shop and some to poor sources of supply picked by the purchasing agent. Such changes can never be entirely eliminated, but there should be a reduction in the matter of model changes, which seem to be one of the biggest curses in the industry. Model changes are justified to Colonel Downey only if they are necessary to give the public a much superior vehicle for the same price or less. Model changes frequently involve a cost of about one million dollars, which must be passed on to the customer.

Such changes are a child of this particular industry. Buyers of automobiles do not every year change their homes, their furniture, pianos or many other articles that go to make up the home. Elimination of unnecessary model changes will result in economy.

Colonel Downey confessed that the art department of the Chrysler Corp. has spent much effort in developing new louvres. After reading a recent booklet, entitled "The Specialist," he expects to see louvres at the New York Automobile Show in the forms of stars and crescents.

Yancey a Surprise Speaker

Metropolitan Section Argues Front Drives and Hears Inside Story of Rome Flight

THE Metropolitan Section scheduled a front-drive meeting for Nov. 21, and had a good meeting, with plenty of discussion, but Capt. Lewis A. Yancey's story of his flight from Old Orchard, Maine, to Rome, with Lieut. Roger Q. Williams, was the most absorbingly interesting part of the meeting. He was introduced by Past-Chairman Sidney R. Dresser, immediately following the dinner at the A.W.A. Clubhouse. Captain Yancey remarked that every event reported in the newspapers has an inside story which does not ordinarily get into print, and took into his confidence the 206 members and guests with the inside story of a successful transatlantic flight.

Salesmanship was required at the outset to gain the support of the makers of both the airplane and the engine to the extent of a thorough overhauling of the three-year-old Bellanca airplane that was used. During this process, in which the fliers participated, they were introduced to what Captain Yancey described as an international understanding that transatlantic fliers must be fed on nothing but fried chicken. Lunches and dinners came in rapid succession, each with the same central item in the menu. When the overhaulings were completed, the fliers were assured that they had the best plane in the world for the trip and that the engine would run 100 hr. without stopping. If it stopped on the way across, they might send it back and get a new one.

After making arrangements with Dr. Kimball, of the Weather Bureau in New York City, for weather information, the fliers went to the Maine coast for further preparation, the chief item of which was 137 hr. of practice in flying blind. The importance of such practice had been impressed upon them at the time of the Dole race to Hawaii, in which Captain Yancey failed to participate because of an accident. Little was known of blind flying at that time, and that probably accounts for the high percentage of fatalities in the Dole race. The hour when darkness falls usually is the supreme test, according to Captain Yancey, as the flier then has nothing but his instruments to rely upon and may allow himself to be fooled by them.

Flying from Maine to Rome

The Rome fliers finally received a favorable report from Dr. Kimball at 2 o'clock one morning, before they had gone to bed, and proceeded immediately to the final preparations. The gasoline supply of 432 gal. was strained 10 times by representatives of the oil company, and a tank containing 20 gal. of oil took the place of the seats in the cabin.

A heavy local fog complicated the beginning of the flight, and blind flying proved much more difficult with heavily loaded tanks than it had been during the practice. It was arranged that Lieutenant Williams, who was at the controls, should watch some of the instruments and Captain Yancey should watch the others, pointing a pencil to any instrument that particularly required the pilot's attention. Captain Yancey described himself as a xylophone player in the rapidity of his action as he pointed to one dial after another. When they finally rose over the fog, the pilot, he said, was sweating one-inch drops and had his eyes almost popping out but fortunately was too busy to notice how the avigator looked.

Flying was easy through the rest of the day. The engine was slowed down to 1550 r.p.m., corresponding to a cruising speed of 85 m.p.h. and observation showed that a tail wind was increasing the ground—or water—speed to 115 m.p.h. much of the time.

When darkness came, no difficulty was experienced in controlling the plane by aid of the instruments, in its lightened condition. The chief trouble was in keeping awake. Captain Yancey described himself as watching the instrument board, leaning out of the window, and biting his tongue to keep awake while Lieutenant Williams slept. Once he fell asleep at the controls and awoke with the engine roaring and the moon spinning around. Centrifugal force from the spin made it almost impossible for him to move his foot; but he managed to right the plane, and the chief loss seemed to be that the cushions over the oil tank, on which they were sitting, flew out the open windows and the rivets on the hot oil-tank felt like blow-torches during the remainder of the flight.

Muller Champions Front-Wheel Drives

The paper of the evening, on the subject of Front-Wheel Drives, was read by W. J. Muller, engineer of New Era Motors, Inc., who mentioned the wide

variation in advantages claimed for the design, and placed emphasis upon the possibility of arranging for the comfort of the passengers without restriction from the mechanical parts of the car, which are segregated in front of the dash, and upon the small unsprung weight, particularly at the rear axle. Entire freedom from wheel-fight and shimmy, small front-tire wear and little tire slippage are claimed for the Ruxton car, although the steering-gear is fully reversible.

Difficulties in front-drive design include provision for driving the radiator fan and providing against excessive powerplant length. Excessive length has been avoided in the Ruxton by placing one-half of the transmission in front of the worm-gear drive. The fan has been driven by belt from an auxiliary shaft in the transmission, but a recent change makes it possible to drive from a pully back of the flywheel.

Praise for Low Unsprung Weight

P. M. Heldt contributed theoretical discussion, in which he credited the lower unsprung weight at the rear with reducing the tendency to rear-wheel skidding. Herbert Chase mentioned the possibility of using a single oiling system for all the chief mechanical parts of the car, and cited an adjustable wedge at the spring-seat of one of the front-drive models as evidence that the design is sensitive to shimmy. He also referred to low front-tire mileage, which he thought not to be an inevitable result of the design. Past-President George W. Dunham emphasized the importance of the low unsprung weight in securing riding comfort.

D. G. Roos, chief engineer of the Studebaker Corp., predicted an unfavorable reaction to cars having doors extending less than 68-70 in. from the ground. He said that the best effect of the front-drive car will be the resulting impulse to improve the chassis of the rear-drive car. F. H. Dutcher, of Columbia University, and W. S. James, of the Studebaker Corp., were among others who contributed to the discussion.

Chairman George A. Round introduced as guests Fredrik Lyungstrom, of Stockholm, and Jean Biche, chief engineer of the Levasseur Airplane Co., of Paris, at the close of the dinner. Section representatives on Society committees were elected as follows: Sections Committee, A. L. Beall, of the Vacuum Oil Co.; Nominating Committee, Herbert Chase, of the *American Machinist;* and alternate for the Nominating Committee, George Margolin, chief engineer of the Flexograph Co., Inc.

Light-Alloy Applications

Frank Jardine Tells Dayton Section of Recent Developments in Engine Metals

MAGNESIUM and aluminum alloys and their varied uses in aircraft engines were described by Frank Jardine, chief engineer of the Aluminum Co. of America, at the Nov. 12 meeting of the Dayton Section following the get-together dinner at the Dayton Engineers Club. Mr. Jardine substituted most acceptably for G. D. Welty, of the same company, who was the scheduled speaker on the subject but was unable to be present. Eighteen members and 16 guests were in attendance and showed their interest by asking Mr. Jardine numerous questions after his presentation of the paper.

The speaker did not bore his hearers by giving extensive data on the physical and chemical properties of the alloys but gave practical information on their application to the various parts of engines, not neglecting to point out the problems and difficulties involved in casting, forging and using metals of new alloy-content. To assure perfect castings of new magnesium alloys, the company examines them by the X-ray method. Gates and risers often have to be changed for making satisfactory castings when the dimensions are altered. Softness of the magnesium alloys as compared with cast iron should be considered in designing parts, and so should the coefficient of expansion and the slow solidification in the heavier sections, which may result in porosity.

Aluminum forgings have proved highly satisfactory in radial-engine crankcases and nose sections in which the design renders their use feasible. When used for connecting-rods, the major factor to consider is the radii, which should be big, as aluminum does not flow readily when hot.

Aluminum Bearings for Nitrided-Steel Journals

Use of aluminum alloys as bearing material against a hardened journal shows much promise, said Mr. Jardine, although it has not been generally accepted by the industry. The new nitrided steels, with their extraordinary surface hardness, furnish the real solution of this problem, and under fair conditions of lubrication the right aluminum alloys will run indefinitely against a nitralloy pin or journal.

Do You Realize the Need of Light Alloys?

Some very promising possibilities are indicated, according to Mr. Jardine, in recent developments in the use in pistons of metals having a lower thermal expansion than aluminum. After many experiments with different piston designs and different metals, and coming to the conclusion that the chances of reducing the coefficient of expansion of aluminum alloy below that of No. 132 are not very promising, efforts were made to find an iron or steel having more than the usual coefficient of expansion. Finally, it was found that the addition of 25 per cent of monel metal to ordinary gray iron gives the iron a coefficient of expansion almost identical with that of aluminum alloy No. 132. This iron is easy to cast and machine and preliminary tests indicate that it possesses very satisfactory bearing characteristics.

Possibilities of Aluminum for Bodies

In conclusion, Mr. Jardine remarked that, while the use of aluminum in automobile crankcases is decreasing, aluminum or magnesium will be used for the crankcases of aeronautic engines. Instead of increasing the size of automobile engines, it would be better to reduce the weight of the car. In Cleveland, he said, the company has a car of 132-in. wheelbase and a cast-aluminum body that weighs between 3000 and 3100 lb. The engine has 3¼ x 4½-in. cylinders. A LaSalle car of 134-in. wheelbase but having a more powerful engine of 92-hp. and fitted with a conventional body of the same type weighs 4800 lb. Although the aluminum car is five years old, it still has a top speed of about 75 m.p.h., outperforms the other and is much cheaper to operate.

Motor-Car Design Reviewed

DISCUSSION held interest at high pitch until after 11 p.m. at a well-attended meeting of the St. Louis Section at the Engineers Club on Nov. 20, following the presentation by A. M. Wolf, of New York City, of a paper on American Passenger-Car design. The paper was an up-to-date revision

of the paper prepared by Mr. Wolf for presentation at the World Engineering Congress held in Tokio, Japan, the first part of the month and was given for the first time in this Country at the St. Louis meeting. A large number of blueprints, photographs and samples were used to exemplify references and descriptions in the paper.

Considerable interest was shown by those present in a new invar-strut piston development by George Dorris, who was present.

The question of upper-cylinder lubrication was raised and is to be carried over as a subject for discussion at the meeting of the Section to be held in December.

History of Light Diesel Engines

Magdeburger Outlines Development of Light Oil-Engines at Pennsylvania Section Meeting

TWO PAPERS were scheduled for presentation at the Nov. 19 meeting of the Pennsylvania Section, which was a joint meeting with the Engineers' Club of Philadelphia, being held in the rooms of the Club. E. C. Magdeburger, Navy Department aide on Diesel engines, came from the City of Washington to give a paper on The Development of High-Speed Oil-Engines, but F. J. Brackett was unable to come from Pontiac, Mich., and his paper on Motor Transport Development was delayed in transit so that it could not be presented. Before the presentation of the Magdeburger paper, J. P. Stewart was elected as the representative of the Section on the Nominating Committee of the Society, and Norman G. Shidle was elected a member of the Sections Committee of the Society. Section-Chairman Dalton Risley, Jr., then handed the gavel to E. B. Neil.

After a brief introduction explaining the desirability of the oil engine, Mr. Magdeburger outlined the development of the lighter or automotive types, beginning with the Maybach engine, built in 1923. This is a relatively large six-cylinder engine for use in rail-cars, provided with air-injection and developing 150 hp. Motorboat engines had been built before this by Hindl, who used hot-air injection into two-cycle cylinders.

Fluid Injection Saves Weight

Fluid injection and gas injection were developed to save the weight and complication of the air compressor. The fluid injection is either by constantly maintained pressure, with needle valves in the individual cylinders, or by direct pumps which combine the injection and metering. The gas-injection type makes use of a precombustion chamber. It was introduced on Vickers' submarine engines and has been used on a number of American high-speed oil-engines, including the Atlas Imperial engines for excavation work. Bessemer railway engines are of this type.

Among the direct fuel-pump injection engines briefly described are the Buda M. A. N.; the Beardmore for the R-101 airship; the Westinghouse; the Dornier; the Brotherhood-Ricardo; and the Ingersoll-Rand, which is said to be the first to be put into a locomotive in this Country. To this class also belong the Junkers and Packard airplane engines.

A peculiarity of the Packard engine, mentioned by Mr. Magdeburger, is that a single valve serves both for exhaust and inlet. This valve opens when the exhaust valve should open and closes when the inlet valve should close, opening directly to the atmosphere. Dr. Dornier had a hand in designing the fuel-injection system of the Packard engine, from which it is inferred that the engine is similar to the Dornier engine in this particular.

Among the precombustion engines to which attention was given are the Fairbanks-Morse; the Brons & Hord; the Deutz; the Benz, together with the Bosch fuel-pump used therein; and the Colo-Diesel, in which a steel plug mounted in the center of the piston produces turbulence in the precombustion chamber and confines the heavy pressure at the beginning of the power stroke. The Hill engine manufactured in this Country is similar, and the Cummins engine is said to be somewhat related, although it does not make use of precombustion.

Attention was given also to supercharging as a means of increasing power. This can be utilized in the Diesel engine without danger of preignition.

Diesels on Motorcoaches

H. A. Hegeman and E. R. Hailer, of the Mercedes-Benz Co., when called upon, gave additional information on the design of their Diesel engines. They also said that one of their truck-type engines has been installed in a motorcoach of the Public Service Coordinated Transport of New Jersey, and that another engine, such as is in regular motorcoach service in Europe, will soon be installed in another New Jersey vehicle.

Capt. R. W. A. Brewer mentioned the problem of metering the very small charge of fuel as one of the major difficulties in small Diesel engines. He spoke of his observation of the Packard aeronautic engine and the ease of starting it with a cartridge inserted in one cylinder. In reply to a question from him, Mr. Magdeburger said that the Packard engine has one small fuel-pump for each cylinder, with a short pipe from the pump to the injector.

Dalton Risley, Jr., Chairman of the Section; F. L. Creager, of the Victor Talking Machine Co.; and J. W. Wagner, of the Westinghouse company, were among the others who contributed to the discussion. A question regarding the possible speed of Diesel engines begged an answer until Mr. Wagner reported that test engines have been operated at more than 2200 r.p.m., with a brake mean effective pressure of 100 lb. per sq. in. and a maximum cylinder pressure of less than 800 lb. per sq. in. Fuel economy was sacrificed slightly to keep the maximum pressure down. He said that the limiting speed of the Diesel engine is not inherent in the cycle.

Course in Service Station Management

IN COOPERATION with the New England Section of the Society, the Massachusetts Division of University Extension in Boston, of which James A. Moyer, a Councilor of the Society, is director, is offering two extension courses of study in automotive subjects. One course is in advanced practice in automotive electricity and consists of eight lessons, the first of which was given on Nov. 4. The other is a course in automobile repair-shop and service-station management, and consists of eight lectures, of which the first was given on Nov. 13. The lectures in the courses are given at the Massachusetts Institute of Technology, in Cambridge.

Subjects included in the second course are: automotive service-station business; organizing the enterprise, personnel and employment; maintenance and repair; parts department and purchasing; operation and control; and advertising and business policy. This course presents the combined management experience of the successful small owner and the consulting expert, as well as the contributions of several leading automobile manufacturers.

Student-Branch Meeting in Flint

ONE OF THE most enthusiastic meetings so far held by the S.A.E. Student Branch at the General Motors Institute of Technology, in Flint, Mich., was that in November, which was featured by an interesting talk by J. A. Faucher, of the aeronautic division of

the United States Rubber Co. Because of his war-period aeronautic training and his connection with commercial aviation, the speaker was in position to give a large number of facts pertaining to aviation as an industry and present an interesting point of view on the possibilities of aircraft operation in the commercial field.

As indicative of the rapid progress of aviation, Mr. Faucher pointed out that the non-stop non-refueling record for an airplane has advanced in the last 19 years from 80 to approximately 4480 miles. Soaring with powerless gliders has been perfected in Germany to such an extent and the gliders so improved that flight has recently been sustained for 14 hr.

Regarding the safety of commercial air-travel, Mr. Faucher asserted that beyond doubt it is greater per miles traveled than railroad travel. Because of the comparative novelty of aviation, however, the occasional accidents in which inexperienced or incapable pilots are involved or a crash occurs in test flying afford the eager reporter an opportunity to cater to the excitement-craving public.

Earle Williams, Chairman of the Branch, presided at the meeting, and Eugene Strunk, Vice-Chairman, was toastmaster of the evening.

Commercial Flying Featured

Indiana Section Told about Major Factors of Air-Transport Success by Three Speakers

DEVELOPMENT, experience and accomplishments of commercial aviation were featured at the meeting of the Indiana Section held at the Hotel Severin, Indianapolis, Nov. 14. Dinner was served in the Roof Garden of the Hotel to 140 members and guests. Bert Dingley, Chairman of the Section, presided at the technical session and the speakers were greeted by an audience of 400, a record attendance.

Motion pictures of air-mail and express lines were shown, and this exhibition was followed by the presentation of three papers, respectively by E. P. Lott, operations manager for the National Air Transport; Charles S. Jones, president of the Curtiss-Wright Flying Service; and Paul Henderson, who, as Assistant Postmaster General, developed the United States Air Mail and is now vice-president of both the Transcontinental Air Transport and the National Air Transport. Mr. Lott's subject was Operation Experience, Mr. Jones spoke on Student Training, and Mr. Henderson's paper was entitled, The Development Facts of Commercial Aviation.

Operating Experience Related

Mr. Lott said that aviation in this Country, although sometimes held to be lagging behind European development, is on a more stable basis because most foreign airlines are controlled or aided by the government, whereas in the United States they are almost entirely in the hands of private interests.

The speaker also dealt with the development of air-mail and express transport, recalling that in 1925 the New York City - San Francisco route was the only one in operation and that the first express service was inaugurated in 1927. Development of night flying has been a great step forward, he said, because it reduces the loss of business time. Bad weather was declared by Mr. Lott to be the principal stumbling block in the path of commercial aviation, although radio service has proved of untold assistance to the airmen.

LOADING EXPRESS PACKAGES INTO A NATIONAL AIR TRANSPORT AIRPLANE FOR SHIPMENT

Training of Student Fliers

Mr. Jones, nationally known as an instructor of student fliers, remarked in part that aviation is a young man's business. Men beyond 60 years of age are becoming good pilots, he said, but the work of carrying on commercial aviation must rest upon the shoulders of youth. Most air blunders in the past have been caused by lack of understanding of fliers or flying psychology, he declared, and today almost all big aviation posts are held by experienced air pilots. Amusing incidents of his experiences as a flier and as a student instructor were related.

Problems of Commercial Flying

Aviation is a new type of transportation which not only has its own appeal and will find its own place but, because of its peculiar characteristics, will be essential as a military aid to our Country, said Mr. Henderson. To find peace-time employment for aviation, we are trying to better ourselves by taking advantage of the speed that aviation offers in the transportation of mail and passengers and also to provide automatically an industrial background that will protect us in the event of defensive or aggressive war.

The air mail, remarked Mr. Henderson, can be said to be thoroughly established in the United States. Twenty-one companies are engaged in transporting mail, which indicates that the business can be classed as competitive rather than monopolistic. About 99 per cent of the business of the National Air Transport in 1928 was with the Post Office Department but, although it is very comforting to have one rich customer, it is bad to have only one customer. Therefore the operating

(*Concluded on p. 702*)

Personal Notes of the Members

Treasurer Whittelsey Accepts Post of Honor

On Nov. 4, Charles B. Whittelsey, Sr., vice-president of the Hartford Rubber Works Co. and Treasurer of the Society, entered upon his duties as executive vice-president of the Hartford, Conn., Chamber of Commerce, succeeding William H. Corbin, who was recently elected president of that organization. Mr. Whittelsey has been a member of the Chamber since 1914. The sentiment that led to the unanimous election of Mr. Whittelsey to this position of distinction was aptly expressed by an officer of the Chamber:

> When the announcement was made that the United States Rubber Co. had decided to move the Hartford plant to Detroit, it was felt in Hartford that the city was losing an integral part of its manufacturing interests, and, while this is as true today as it was a month ago, there will be much gratification expressed over the fact that if Hartford cannot keep the rubber plant it can keep the man who played so important a part in the industry's progress. The big change in the United States Rubber Co.'s plans meant Mr. Whittelsey's removal to Detroit, and, while he would doubtless gain from a finansial standpoint, he would lose all contacts in the city of which he is so fond.

Mr. Whittelsey has rendered distinguished service to both the industry and the Society. He had been connected with the Hartford Rubber Works Co. since 1901. Eighteen years ago he was made factory manager and in 1913 was elected vice-president of the company. He was its president from 1916 to 1927, and again vice-president from the latter year to the time of his retirement. He was a director of the Hartford County Manufacturers Association from 1911 to 1927, and its president during 1917 and 1918.

Since becoming an Associate Member of the Society in 1910, Mr. Whittelsey has given unsparingly of both his time and effort to the work of the organization. In 1911 he served as a member of the Division for Wood-Wheel Dimensions and Fastenings for Solid Tires, of the Standards Committee. Elected to Member grade in October, 1911, he was appointed a member of the Truck Standards Division of the Standards Committee and a member of the S.A.E. Council for 1912 and 1913. In 1914 he served on the following Divisions of the Standards Committee: Commercial-Car Wheels, Pleasure-Car Wheels, and Truck Standards. During 1915 he remained on the two last-named Divisions and served also as a member of the International Standards Division, and in 1916 and 1917 was a member of the Tire and Rim Division of the Standards Committee.

Mr. Whittelsey became a Life Member of the Society in 1916, and was elected Treasurer in 1918, an office that he has retained to the present time. He has also been a member of the Society's Finance Committee for many years.

Two papers by Mr. Whittelsey were published in TRANSACTIONS: Solid Motor Tires, in Part 1 of 1912, p. 322; and Pros and Cons of Tire Inflation, Part 1 of 1915, p. 195.

Keller Made Chrysler General Manager

Promotion of K. T. Keller from vice-president in charge of production of the Chrysler Corp. to vice-president and general manager of all divisions marks another forward step in the career of this engineer, who has been associated

CHARLES B. WHITTELSEY

with the automotive industry almost from its earliest days.

Mr. Keller's first position, from 1906 to 1910, was with the Westinghouse Machine Co. In 1910 he became general inspector of the Steel Products Co., and later that year accepted the position of general foreman for the Metzger Motor Car Co. From 1911 to 1912 he was chief inspector at the Tarrytown, N. Y., plant of the Maxwell-Briscoe Motor Co., and subsequently became general superintendent of the Northway Motors Co., which post he held until 1916, when he joined the Cole Motor Co. to work on factory equipment material sources and car design, service, and factory operations. After serving the Buick Motor Co. from 1917 to 1919 as general master mechanic, he was put in charge of special work for the General Motors Corp., and in 1921 became manager of manufacturing for the Chevrolet Motor Co. In 1923 he was named manufacturing executive of this company, and the following year became vice-president and general manager of General Motors of Canada.

He accepted the post of vice-president in charge of manufacturing for the Chrysler Corp. in 1926, and became general manager of the Dodge Brothers Corp.

Mr. Keller joined the Society in May, 1922, being elected to Member grade, and wrote a paper on Basic Factors of Production, which was printed in THE JOURNAL for November, 1925, p. 494. Another paper, on Production Leadership, was published in the S.A.E. JOURNAL for December, 1928, p. 554.

Congressional Medal for Fairbanks

In consideration of exceptionally meritorious service rendered as signal officer of the 5th Army Corps from Aug. 25 to Nov. 20, 1918, William H. Fairbanks, lieutenant-colonel in the reserve, and Chairman of the Society's Southern California Section, was presented with the Distinguished Service Medal of the United States Government on Aug. 19. The presentation, made by Col. Roger Fitch, commanding officer of Camp Del Monte, was the second occasion of Colonel Fairbanks receiving Congressional distinction, the first being the award to him of the Philippine Congressional Medal for services in Luzon during the Spanish-American War and the Philippine insurrection.

Colonel Fairbanks has been connected for more than 27 years with the Southern California Telephone Co. and its predecessors. At present he holds the position of general supervisor of the Bell Telephone System motor-vehicle equipment in Southern California.

A Member of the Society since 1925, Colonel Fairbanks is Chairman of the Southern California Section. A paper entitled, Operating Costs and Economic Life of Motor-Vehicles, written by him and presented at a meeting of the Southern California Section, was publshed in THE JOURNAL for March, 1926, p. 285.

Chenoweth with General Motors Research

Opie Chenoweth has severed his connection as mechanical engineer of the Materiel Division of the Air Corps, at Wright Field, Dayton, to become research engineer with the General Motors Corp. Research Laboratories.

After being graduated with the degree of B.S.M.E. from Purdue University, where he had written an undergraduate thesis on The Effect of Various Heaters on the Performance of a Cadillac Car Determined by Road Test, Mr. Chenoweth worked for the People's Loan & Trust Co., of Winchester, Ind., from 1921 to 1922, and then for one year at Purdue University as general research assistant. He was connected from 1923 to 1927, as development engineer, with the Engineering Division of the Air Corps at Dayton, then devoted himself to carbureter design with the Wheeler-Schebler Carburetor Co. After some months, he accepted the position with the Materiel Division from which he lately resigned.

In October, 1921, Mr. Chenoweth became a Junior Member of the Society, and last May was transferred to Member grade. A paper presented by Mr. Chenoweth at the Aeronautic Meeting of the Society in October, 1927, entitled Supercharged Engine Performance, Calculated and Actual, was printed in the S.A.E. JOURNAL for November, 1927, p. 508.

K. T. KELLER

ROBERT F. KOHR

Kohr Connected with Bendix

Announcement has been made that Robert F. Kohr, formerly connected with the Studebaker Corp., is now engaged in brake-development work in the engineering department of the Bendix Co., of South Bend, Ind. He brings to his new position a wide and varied experience in automotive and aircraft matters.

After receiving his degree of Bachelor of Science of Mechanical Engineering from the University of Michigan in the summer of 1917, Mr. Kohr joined the United States Army. He was commissioned a second lieutenant and was stationed at Camp Lee, Va., with the 305th Engineers and was second in command of the engineers train. In January, 1918, he was transferred to the 24th Engineers at Camp Dix, N. J., whence he was sent to embarcation and overseas in March to join the American Expeditionary Forces. In France he was attached to the 301st heavy battalion of the United States Tank Corps, after taking several courses in British Tank Schools, and he saw active service as commander of a tank on the Hindenburg line.

Subsequent to his discharge from the service, in February, 1919, Mr. Kohr became a partner in the firm of Smith & Kohr, engaged in the tractor-sales and service and motor-repair business in Rockville, Md. This and similar work engaged him until February, 1920, when he became a mechanic in the Motor Transport Corps, working on airplane-engine research under the direction of the Bureau of Standards. In April, 1920, he was promoted to the position of assistant mechanical engineer and specialized on the subjects of engine research and fuel heating. The following year he was made associate mechanical engineer in the Bureau and remained there until, in 1926, he was transferred as aeronautical engineer to the Bureau of Aeronautics of the Navy. His work at the Bureau included development of ballast-water recovery apparatus for aircraft of the Army Air Service.

In September, 1926, Mr. Kohr left the Government service to become laboratory engineer of the Studebaker Corp. of America, in the company's engineering department at South Bend, where he remained until his recent resignation.

Mr. Kohr became a member of the Society in 1920 and joined the Washington Section, which he served as Secretary in 1925 and as Chairman during the following year.

Herman Now Chief Engineer

Two and a half years after entering the employment of the DivCo-Detroit Corp., Kenneth R. Herman has been promoted to the position of chief engineer. He has been connected with the automotive industry ever since 1915, when he was graduated from the Manual Arts High School, in Los Angeles. From June, 1915, to July, 1916, he was assistant buyer for the Harper Reynolds Co., wholesale dealer in machine-shop supplies and hardware, in Los Angeles, and during the following 18 months acted as stock clerk and salesman for John Wigmore & Sons, of the same city.

In December, 1917, Mr. Herman became connected with the Kimball Motor Truck Co., of Los Angeles, in the capacity of draftsman, and was repeatedly promoted, becoming in turn superintendent and chief engineering designer, and being in complete charge of design and manufacture of both motor-trucks and motorcoaches from 1920 to 1925. He accepted a position as a designer of engines and chassis with the Oakland Motor Car Co., of Pontiac, Mich., in 1926, and in April of the following year became affiliated with the DivCo-Detroit Corp., as an assistant engineer.

Mr. Herman was elected Junior Member of the Society in 1919, and was transferred to Member grade in 1928.

Litle Enters New Field

Thomas J. Litle, Jr., has resigned as chief engineer of the Marmon Motor Car Co., a post he has held since 1927, to take up the occupation of engineering counsel and consulting industrialist.

OPIE CHENOWETH

W. H. FAIRBANKS

(*Continued on p.* 40)

Applicants Qualified

The following applicants have qualified for admission to the Society between Oct. 10 and Nov. 10, 1929. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

ALLEN, WILLIAM G. (A) shop foreman, Allen Motor Co., *Elkader, Iowa.*

ALLISON, JOHN M., JR. (J) assistant aeronautical engineer, Navy Department, United States Naval Air Station, A. & R. Department, *Lakehurst, N. J.*

ALTIER, DONALD (A) roadman, The Buda Co., *Harvey, Ill.;* (mail) 15701 Lexington.

ALTREE, A. C. (A) manager, manufacturers sales, Pacific Coast branch, American Bosch Magneto Corp., 1262 Post Street, *San Francisco.*

BATTEY, ALEXANDER J. (M) experimental engineer, spark-plug division, A. C. Spark Plug Co., *Flint, Mich.;* (mail) 1821 Lawndale Avenue.

BOECK, ELLSWORTH R. (A) president, Truck Equipment Co., Inc., 1791 Fillmore Avenue, *Buffalo.*

BOONE, ANDREW RICHMOND (A) 613 Spreckels Theatre Building, *San Diego, Calif.*

BOWEN, WILLIAM H. (J) mechanic, draftsman, aeronautics department, California Institute of Technology, *Pasadena, Calif.;* (mail) 1671 Locust Street.

BRENNER, HERBERT J. (A) district manager, Willis-Jones Machinery Co., Inc., Seattle, Wash.; (mail) 655 52nd Street, *Milwaukee.*

BROWN, ALEXANDER H., JR. (J) engineer, General Electric Co., *Schenectady, N. Y.;* (mail) 1079 Maryland Avenue.

CHADBOURNE, LE ROY (J) engineer, Wright Aeronautical Corp., Paterson, N. J.; (mail) 251 A South Irving St., *Ridgewood, N. J.*

GIBNEY, LYMAN H. (A) president, general manager, Associated Die & Tool Co., *Flint, Mich.;* (mail) 601 West Water Street.

HAYES, IRA C. (J) mechanical draftsman, Barnes-Gibson-Raymond, Inc., *Detroit;* (mail) 1774 Seward Avenue.

HOFFMAN, SAMUEL K. (J) junior engineer, aircraft engine division, Cadillac Motor Car Co., Michigan Boulevard, *Detroit;* (mail) 151 Seward Avenue.

JACOBUS, DALE P. (J) Foster-Vernay Corp., Metropolitan and Woodward Avenues, *Brooklyn, N. Y.*

JOHNSON, ANDOR W. (A) in charge of dynamometers, Eisemann Magneto Corp., *Brooklyn, N. Y.;* (mail) 422 48th Street.

JUDGE, FRANCIS H. (A) district manager, Western Felt Works, *Cleveland;* (mail) 750 Prospect Avenue.

KIMMERLING, F. S. (A) president, general manager, Guide Lamp Corp., *Anderson, Ind.*

LAING, GEORGE (M) lecturer in motor engineering, Druleigh College, *Auckland, New Zealand;* (mail) 16 Picton Street, Ponsonby, Auckland.

LAUTZ, CARL F. (M) installation engineer, Houde Engineering Corp., *Buffalo.*

LONG, MATHEW RAYMOND (A) shop foreman, H. T. Swanson Motor Co., *Port Angeles, Wash.;* (mail) 432 East Fifth Street.

LUNDQUIST, WILTON G. (J) engineering department, Wright Aeronautical Corp., *Paterson, N. J.*

MOFFETT, RICHARD JOHN (M) chief technician, aircraft section, Canadian Vickers, Ltd., Maissoneuve, *Montreal, Que., Canada;* (mail) 14A-940, Decarie Boulevard.

OBERLE, FRANZ (J) field representative, Robert Bosch Magneto Co., Inc., Long Island City, N. Y.; (mail) 1122 South Michigan Avenue, *Chicago.*

OLIVER, CHRISTOPHER SIBLEY (F M) works manager, Humber, Ltd., *Coventry, England.*

PAGE, GEORGE A., JR. (M) design engineer, Curtiss Aeroplane & Motor Co., Inc., *Garden City, L. I., N. Y.*

PARKER, FRED W., JR. (J) sales engineering department, Timken-Detroit Axle Co., 100-400 Clark Avenue, *Detroit.*

PEPPERS, CHARLES C. (A) president, Peppers Gasoline Co., Box 858, *Enid, Okla.*

PERRY, ROBERT J. (A) sales promotion, C. R. Robinson Sales Co., 16549 Woodward Avenue, *Detroit;* (mail) 2183 Lenox Avenue.

PHILIPPI, HOWARD (J) draftsman, Fokker Aircraft Corp., Teterboro, N. J.; (mail) Y.M.C.A., *Hackensack, N. J.*

PRICE, EDGAR E. (A) sales manager, U. S. L. Battery, Ltd., 1352 Dufferin St., *Toronto, Ont., Canada;* (mail) 124 St. Germain Avenue, Toronto 12.

PROUDFOOT, DAVID GIBB (M) research department, Sun Oil Co., 5848 Brooklyn Avenue, *Detroit.*

RIDDELL, ROSS A. (M) trouble man, Cadillac Motor Car Co., 6426 Maxwell Avenue, *Detroit.*

ROGERS, WALTER (J) draftsman, Caterpillar Tractor Co., San Leandro, Calif.; (mail) 310 Athol Avenue, *Oakland, Calif.*

ROSA, LEONARD J. (A) sales manager, Kelsey-Hayes Wheel Co., 3600 Military Avenue, *Detroit.*

SEAMAN, MILTON L. (J) student, University of Maryland, College Park, Md.; (mail) 207 Baltimore Avenue, *Takoma Park, Md.*

SCHROEDER, CARL A. P. (J) layout man, engineering department, Timken-Detroit Axle Co., Clark Avenue at Fort St., *Detroit;* (mail) 6553 Woodward Avenue.

SEALE, SIDNEY COLEMAN (S M) chief machinist, United States Navy, Fitzsimmons General Hospital, *Denver.*

SHADOFF, WILLIAM (A) service manager, R. N. Wickett, Inc., 2521 Colby, *Everett, Wash.*

VAILLANCOURT, JEREMIE ALEXANDRE (J) body engineer, M. P. Moller Motor Car Co., *Hagerstown, Md.;* 703 Sunset Avenue.

WARDWELL, JOHN S. (A) sales representative, Timken-Detroit Axle Co., 100-400 Clark Avenue, *Detroit.*

WERMINE, H. H. (M) research engineer, Belden Mfg. Co., 2300 South Western Avenue, *Chicago.*

WHITE, CHARLES E. (J) draftsman, Foote Brothers Gear & Machine Co., 212 Leach Avenue, *Joliet, Ill.*

News of Section Meetings

(*Concluded from p. 699*)

company has been struggling to develop other traffic to supplement the air-mail transport.

Speaking of the slow development of the air-express business, Mr. Henderson remarked that this service is used mainly for emergency shipment of goods such as urgently needed surgical instruments and repair parts for machinery; however, he believes that the express business will increase.

Regarding the development of passenger air-travel, the speaker remarked that such service must be made at the start as complete as it will be later when carrying many passengers, and therefore the initial expense is very great compared with the income. He advanced the belief that this condition can be met by offering more frequent airplane services at much lower rates which, he thinks, should be but little higher than present railroad fares.

O. S. U. Student Branch Meetings

FOLLOWING a dinner meeting of the S.A.E. Student Branch of Ohio State University, on Oct. 24, Prof. K. E. Stinson, of the mechanical engineering department of the University, gave a talk on the design of airplane engines. The addess was illustrated with lantern slides of various engines and the speaker traced the development of the airplane engine, showing what engineers have learned by experience. This was followed by discussion on the subject.

At a second meeting, held on Nov. 7, and attended by two score student members, the speaker after the dinner was Phillip K. Knight, a member of the Branch, who talked about front-wheel drives. He reviewed the history and evolution of this type of motor-vehicle and described several European constructions and the two American front-wheel-drive cars on the market. Considerable discussion was evoked by the speaker's explanation of the theories of this drive and the application of them as made by the various automobile companies. All who were present enjoyed the discussion so much that the desire was general to have another meeting on the same subject after the theories have had sufficient trial in actual operation of the cars.

Applicants for Membership

The applications for membership received between Oct. 15 and Nov. 15, 1929, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

Atkins, Frank D., automobile sales and service, Atkins' Motor Co., *Oakland, Calif.*

Bach, A. W., engineering, International Harvester Co., *Chicago.*

Baker, P. D., engineer, Clark Brothers Co., *Olean, N. Y.*

Barry, Henry B., major, Quartermaster Corps, U. S. A., *City of Washington.*

Battenfeld, C. F., president and general manager, C. F. Battenfeld Oil Co., *Detroit.*

Beers, George H., superintendent, Walker Body Co., *Amesbury, Mass.*

Berkow, Murray, experimental engineer, Bellanca Aircraft Co., *New Castle, Del.*

Bock, Karl W., branch manager, Mack Truck Co., *Omaha, Neb.*

Bonal, A., engineer in purchasing department, Société des Automobiles Peugeot, *Paris, France.*

Brooks, Roy Oakland, manager of Northern California branches, Standard Safety Corp., *Los Angeles.*

Brownell, J. L., consulting engineer, Checker Cab Mfg. Corp., *Kalamazoo, Mich.*

Burkholder, Fred O., vice-president and sales manager, Ahlberg Bearing Co., *Chicago.*

Carlson, Petrus Albert, chief engineer, Commercial Aircraft Co. of America, *Bridgeport, Conn.*

Cessna, Eldon W., assistant chief engineer, Cessna Aircraft Co., *Wichita, Kan.*

Chelle, Serge, truck and motorcoach specialist, General Motors France, *Paris, France.*

Clarke, Robert Huntley, assistant mechanical engineer, Powerplant Branch, Wright Field, *Dayton, Ohio.*

Coates, John, manager truck and bus division, General Motors N. Z. Ltd., *Wellington, New Zealand.*

Cummings, John, designing engineer on steel-constructed bodies, Studebaker Corp., *South Bend, Ind.*

Cunningham, William W., draftsman, Consolidated Aircraft Co., *Buffalo.*

Dalton, Charles J., owner, Charles J. Dalton Corp., *New York City.*

Deletaille, Emile, manager of automobile and motorcycle division, Fabrique National d'Armes de Guerre, *Liège, Belgium.*

Denes, Hugo, Denes & Friedmann A. G., *Vienna 18, Austria.*

Drohman, Laurence H., time study, National Twist Drill & Tool Co., *Detroit.*

Edgerton, R. G., president and chief engineer, Motor-Car Ventilator Corp., *Suffolk, Va.*

Enke, Paul A., sales correspondent, Johns-Manville Corp., *Chicago.*

Everitt, Frederick H., time study, National Twist Drill & Tool Co., *Detroit.*

Fell, William F., electrical engineer, Eclipse Aviation Corp., *East Orange, N. J.*

Frauenfelder, J. Barraja, consulting engineer, J. Barraja-Frauenfelder & Co., *Philadelphia.*

Funkhouser, Mearick, student, Cornell University, *Ithaca, N. Y.*

Gray, Robert A., research engineer, Standard Oil Co. of California, *Oakland, Calif.*

Gresham, A. E., chief engineer, aircraft department, Standard Steel Works, *North Kansas City, Mo.*

Gottron, Robert E., engine-layout draftsman, Cadillac Motor Car Co., *Detroit.*

Heinze, Albert F., salesman, Autocar Sales & Service Co., *Los Angeles.*

Hibbard, Hall L., engineer, Stearman Aircraft Co., *Wichita, Kan.*

Hodgson, Samuel Kindley, project engineer, Spartan Aircraft Co., *Tulsa, Okla.*

Holcombe, Ralph M., sales manager, Kenyon Kumfort Kabs, Inc., *Albion, N. Y.*

Holmstrom, John G., chief engineer, Kenworth Motor Truck Corp., *Seattle, Wash.*

Kaminsky, Paul M., proprietor, Carlye Rubber Co., *New York City.*

Kittler, Milton J., engineer experimental department, International Harvester Co., *Chicago.*

Klann, William G., plant manager, Murray Corp. of America, *Detroit.*

Kononoff, Alexis B., student engineer, Buick Motor Co., *Flint, Mich.*

Kurasina, T., head of engineering investigation department, Shilbaura Engineering Works, *Shiba, Tokio, Japan.*

Kusuyama, Kenji, commercial-car specialist and sales representative, General Motors Japan, Ltd., *Osaka, Japan.*

Independent Oil & Gas Co., *Tulsa, Okla.*

Industrial Alcohol Institute, Inc., *New York City.*

Jack, William A., engineer, Burgess Battery Co., *Madison, Wis.*

Johnson, Stephen, Jr., general engineer, automotive brake division, Westinghouse Air Brake Co., *Pittsburgh.*

Linderme, Theodore E., vice-president, Linderme Machine & Tool Co., *Detroit.*

Linderme, Theodore G., president, Linderme Machine & Tool Co., *Detroit.*

Lackner, J. E., lubrication engineer, The Texas Co., *Seattle, Wash.*

Lewis, Richard B., Jr., general manager, Diamond Motor Parts Division, St. Cloud, Minn., and Aluminum Industries, Inc., *Cincinnati.*

Lexow, Frederic R., service manager, Marmon Automobile Co. of New York, *Brooklyn, N. Y.*

Libby, Calvin R., plant-layout engineer, A. J. Brandt Co., *Detroit.*

Lindstrom, Olaf, manager truck and bus division, General Motors Nordiska AB., *Stockholm, Sweden.*

Loening, Albert Palmer, vice-president and director, Keystone Aircraft Corp., *New York City.*

Long, J. F., general manager and chief engineer, J. F. Long, Inc. *Berkeley, Calif.*

Maxwell, Gordon H., laboratory assistant, White Motor Co., *Cleveland.*

McMurray, John C., American Automatic Safety Oil Gauge Co., *Winthrop, Mass.*

Melby, Einar C., transportation engineer, General Motors Export Co., *Pontiac, Mich.*

Merrill, Edward D., president and general manager, Washington Rapid Transit Co., *City of Washington.*

Merrill, George Leroy, chief tool designer, Eaton Axle & Spring Co., *Cleveland.*

Messervy, Arthur Henry, chief body engineer, Smith & Waddington, Ltd., *Sydney, Australia.*

Milhollin, T. J., assistant director of education in charge of automotive schools, United Y.M.C.A. Schools, *Seattle, Wash.*

Moore, C. M., transportation engineer, General Motors Export Co., *New York City.*

Moore, Howard James, manager, parts and service division, Durant Motors of Canada, Ltd., *Leaside, Ont., Canada.*

Nelson, Richard Herman, production manager, Herman Nelson Corp., *Moline, Ill.*

Newcomb, Leroy, engineer, Transportation Management Corp., *New York City.*

Odegaard, Sigurd, automobile-body draftsman and designer, Mack International Motor Truck Corp., *Long Island City, N. Y.*

Payette, Joseph A., technical service department, United States Rubber Co., *Detroit.*

Pease, Arthur Wayne, manager, motor reconditioning service, Pease Bros., *Tacoma, Wash.*

Prest, Clarence O., owner, manager and designing engineer, Prest Airplanes & Motors, *Arlington, Calif.*

Raycroft, Richard Irving, manufacturers' sales representative, Firestone Tire & Rubber Co., *Hamilton, Ont., Canada.*

Riblet, Dale M., Dale M. Riblet Oil Co., *Chicago.*

Richards, R. W., manager of tire sales, Goodyear Tire & Rubber Co., *New Toronto, Ont., Canada.*

Robertson, Ralph N., mechanical engineer, Blaw-Knox Co., *Pittsburgh.*

Ross, Fred W., engineer, Euston Ignition Co., *London, England.*

Ross, William P., lubricating engineer, The Texas Co., *Detroit.*

Roth, Karl M., manager, Air Industries Foundry Co., *Wichita, Kan.*

Ruskin, Henry, draftsman, Curtiss Aeroplane & Motor Co., *Buffalo.*

Schjolin, Hans O., project engineer, General Motors Truck Co., *Pontiac, Mich.*

Schultz, Arthur B., chief engineer, Hise Aircraft Corp., *Detroit.*

Severino, Maurice J., division service manager, Mack International Motor Truck Corp., *Albany, N. Y.*

Sharp, George Edward, chief draftsman, Dunlop Rim & Wheel Co., Ltd., Holbrook Lane, *Coventry, England.*

Sibert, Charles J., engineering department, General Electric Co., *Detroit.*

Sieger, George N., technical advisor, Carboloy Co., Inc., *New York City.*

Sieglaff, Arthur W., president and general manager, Zenith Mfg. Corp., *Milwaukee.*

Smith, Noah B., owner, Smith, Rudy & Co., *Philadelphia.*

Smith, William Henry, sales engineer, General Motors Export Co., *New York City.*

Staley, Fabian R., editor, *Refining, Tulsa, Okla.*

Steindler, Julius, managing director, Denes & Friedmann A. G., *Vienna 18, Mitterberggasse, Austria.*

Sporkhorft, Dr. A., Hansa-Automobilewerke A. G., Varel, *Oldenburg, Germany.*

Strehlow, Walter F., engineer, Allis-Chalmers Mfg. Co., *Milwaukee.*

Sullivan, Harold W., chief chemist, Independent Oil & Gas Co., *Okmulgee, Okla.*

Terrett, Regional St. John, assistant body engineer, General Motors of Canada, Ltd., *Oshawa, Ont., Canada.*

Timm, Frithiof V., transportation engineer, General Motors International A/S, *Copenhagen, Denmark.*

Townsley, Robert E., inspector of motor-vehicles and spare parts, Quartermaster Corps, U. S. A., *Camp Holabird, Baltimore.*

Turner, Gilbert H., assistant to vice-president, Timken Roller Bearing Co., *Canton, Ohio.*

Underwood, Arthur Francis, research engineer, powerplant section, General Motors Research Corp., *Detroit.*

Wells, F. O., president, Wells Mfg. Co., *Greenfield, Mass.*

White, Hollis A., experimental engineer, James Cunningham Son & Co., *Rochester, N. Y.*

Whithead, Ennis Clement, lieutenant, Army Air Corps, Wright Field, *Dayton, Ohio.*

Willis, Ross E., sales manager, Ready-Power Co., *Detroit.*

Wise, William Frederic, sales manager, Ex-Cello Aircraft & Tool Co., *Detroit.*

Woodworth, O. B., assistant service manager, The Buda Co., *Harvey, Ill.*

Wright, Richard N., service manager, Hubert J. Wright, Inc., *Syracuse, N. Y.*

Notes and Reviews

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

AIRCRAFT

Speed and Deceleration Trials of the U.S.S. Los Angeles. By S. J. De France and C. P. Burgess. Report No. 318. Published by the National Advisory Committee for Aeronautics, City of Washington; 20 pp., illustrated. [A-1]

The trials reported herein were instigated by the Bureau of Aeronautics of the Navy Department for the purpose of determining accurately the speed and resistance of the U.S.S. Los Angeles with and without water-recovery apparatus, and to clear up the apparent discrepancies between the speeds attained in service and in the original trials in Germany.

The trials proved very conclusively that the water-recovery apparatus increases the resistance about 20 per cent, which is serious, and shows the importance of developing a type of recovery having less resistance.

Between the American and German speed trials without water recovery there remains an unexplained discrepancy of nearly 6 per cent in speed at a given rate of engine revolutions. Warping of the propeller blades and small cumulative errors of observation seem the most probable causes of the discrepancy.

Aerodynamic Characteristics of Twenty-four Airfoils at High Speeds. By L. J. Briggs and H. L. Dryden. Report No. 319. Published by the National Advisory Committee for Aeronautics, City of Washington; 32 pp., illustrated. [A-1]

The aerodynamic characteristics of 24 airfoils are given for speeds of 0.50, 0.65, 0.80, 0.95 and 1.08 times the speed of sound, as measured in an open-jet airstream 2 in. in diameter, using models of 1-in. chord. The 24 airfoils belong to four general groups. The first is the standard R.A.F. family in general use by the Army and Navy for propeller design, the members of the family differing only in thickness. This family is represented by nine members ranging in thickness from 0.04 to 0.20 in. The second group consists of five members of the Clark-Y family, the members of the family again differing only in thickness. The third group, comprising six members, is a second R.A.F. family in which the position of the maximum ordinate is varied. Combined with two members of the first R.A.F. family, this group represents a variation of maximum ordinate position from 30 to 60 per cent of the chord in two camber-ratios, 0.08 and 0.16. The fourth group consists of three geometrical forms: a flat plate, a wedge, and a segment of a right circular cylinder. In addition, one section used in the Reed metal propeller was included.

These measurements form a part of a general program outlined at a conference on propeller research organized by the National Advisory Committee for Aeronautics, and the work was carried out with the financial assistance of the committee.

The Measurement of Fluctuations of Air Speed by the Hot-Wire Anemometer. By H. L. Dryden and A. M. Kuethe. Report No. 320. Published by the National Advisory Committee for Aeronautics, City of Washington; 26 pp., illustrated. [A-1]

The hot-wire anemometer suggests itself as a promising means for measuring the fluctuating air velocities found in turbulent air-flow. The only obstacle is the presence of a lag due to the limited energy input which makes even a fairly small wire incapable of following rapid fluctuations with accuracy. This paper gives the theory of the lag and describes an experimental arrangement for compensating for the lag for frequencies up to 100 or more per second when the amplitude of the fluctuation is not too great. An experimental test of the accuracy of compensation and some results obtained with the apparatus in a wind-tunnel airstream are described. While the apparatus is very bulky in its present form, the development of a more portable arrangement is believed to be possible.

Solving the Problem of Fog Flying. Published by the Daniel Guggenheim Fund for the Promotion of Aeronautics, Inc., New York City; 52 pp. [A-1]

This pamphlet gives a full report of the activities of the Fund's full-flight laboratory to date, including the experiment made by Lieut. James H. Doolittle at Mitchel Field on Sept. 24, 1929.

Since September, 1926, when the Fund organized an informal committee for the coordination of fog-flying research, several fundamental questions bearing on this research have been undertaken through the employment of specialists or through grants of money to different universities.

British Aircraft at the Olympia Show. Published in *Flight*, July 11, 1929, p. 579. [A-1]

Persons interested in a complete description of the last Olympia Aero Show would do well to refer to the July 11, 18 and 25 issues of *Flight*. The first named contains illustrated descriptions of all the British aircraft exhibited at Olympia; the July 18 issue gives illustrated descriptive articles dealing with all the British aeronautic engines and of the foreign aircraft exhibited at the show. Particulars of the foreign airplane engines, with photographs, appear in the July 25 issue, accompanied by a concluding table giving the main data for all the engines exhibited. In addition, the third-mentioned issue includes detailed descriptions of a large number of accessories, components and equipment, illustrated with sketches.

Similarly, three numbers of *The Aeroplane* are devoted to a complete review of the show. They are the issues of July 12, 24 and 31.

Souvenir of the Schneider Trophy Contests. Published in *Flight*, Sept. 6, 1929, p. 941. [A-1]

This article records the progress and development of the seaplane in the 16 years since the first Schneider Trophy Contest. A short history, together with illustrations, is given of each contest since the first, held in 1913, and diagrams illustrating the increased speed, horsepower, and so forth of the successive contests are included.

Schwingungsuntersuchungen an der Maschinenanlage des Luftschiffes Graf Zeppelin. By Wunibald Kamm and Albert Stieglitz. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Sept. 28, 1929, p. 465. [A-1]

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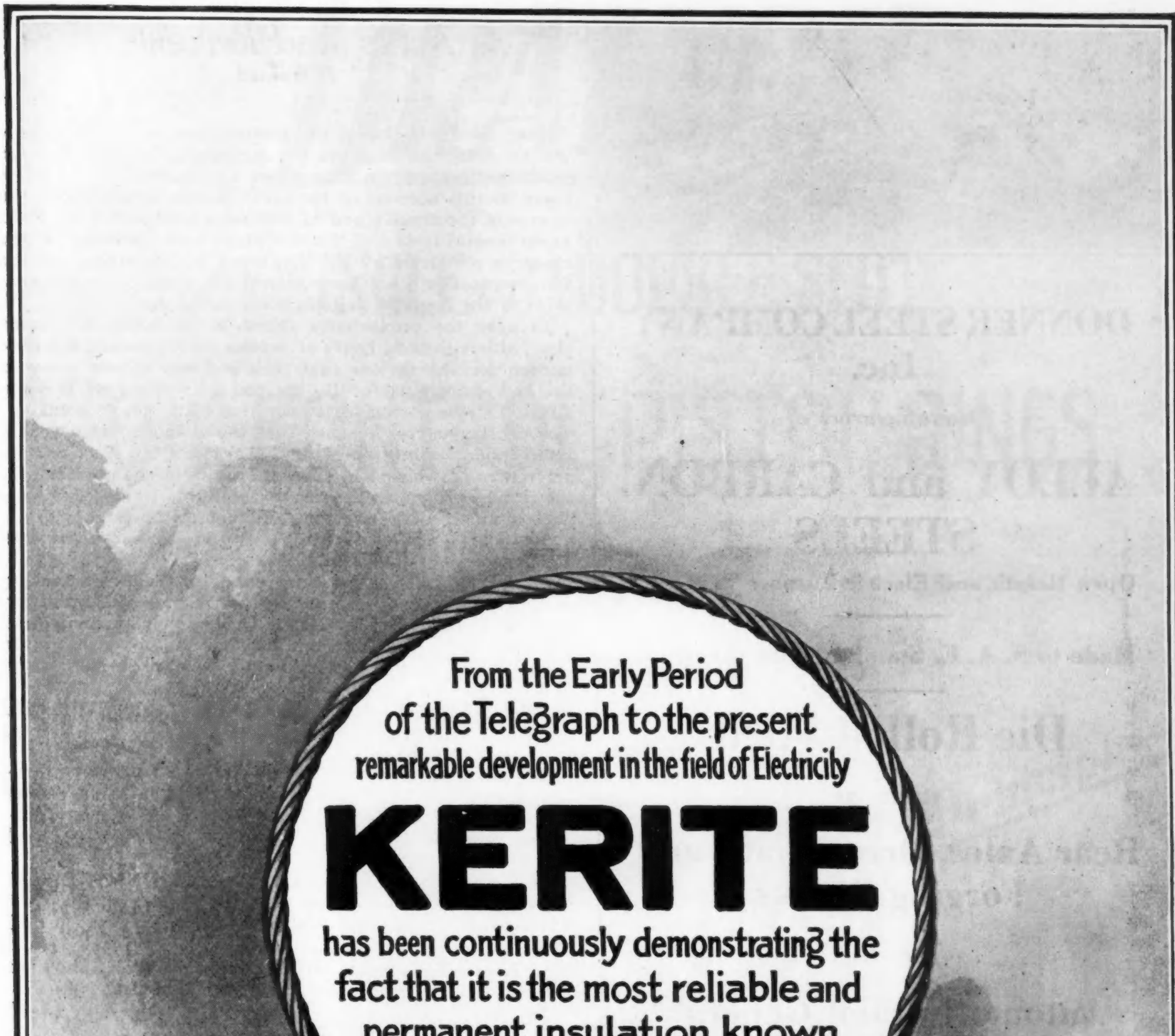
From the Early Period
of the Telegraph to the present
remarkable development in the field of Electricity
KERITE
has been continuously demonstrating the
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Notes and Reviews

Continued

Engineers who recall the interruption in the Graf Zeppelin's American flight in the spring of this year through crankshaft rupture in four of her five engines will be interested in this account of the investigation to determine the causes of the trouble and to discover remedies for it. Both experimental tests and theoretical analysis were used in the research conducted by Dr. H. Thoma, of Karlsruhe, and the German Institute for Aeronautical Research, under the auspices of the Zeppelin and Maybach companies.

Because the crankshafts failed at so nearly the same time, although their hours of service varied widely, the conclusion seemed obvious that they had not merely come to the end of their useful life but had been subjected to some unusual stress during their operation just prior to breaking. The conclusion was reached that the source of the trouble was torsional vibration of the crankshaft, the elastic characteristics of which had been altered by a change made in the clutch spring just before the last flight. Evidence in support of this theory was the fact that all the shafts broke at two places, the location of the two breaks being virtually identical in all the shafts.

How the investigation bore out this theory is told in detail. The remedy adopted was to alter the vibration periods by increasing the elasticity of the clutch spring and lightening the counterweights. The incorporation of a vibration dampener was also found to be advisable.

The Impact on Seaplane Floats During Landing. By Th. von Karman. Technical Note No. 321. [A-1]

The Effect of the Wings of Single-Engine Airplanes on Propulsive Efficiency as Shown by Full-Scale Wind-Tunnel Tests. By Fred E. Weick and Donald H. Wood. Technical Note No. 322. [A-1]

Wind-Tunnel Tests on Airfoil Boundary-Layer Control Using a Backward-Opening Slot. By Montgomery Knight and Millard J. Bamber. Technical Note No. 323. [A-1]

Wind-Tunnel Tests on an Airfoil Equipped with a Split Flap and a Slot. By Millard J. Bamber. Technical Note No. 324. [A-1]

Wind-Tunnel Pressure-Distribution Tests on a Series of Biplane Wing Models. Part II. Effects of Changes in Decalage, Dihedral, Sweepback and Overhang. By Montgomery Knight and Richard W. Noyes. Technical Note No. 325. [A-1]

Part I, Effects of Changes in Stagger and Gap, was published as Technical Note No. 310, which was noted in the S.A.E. JOURNAL for September.

Wind-Tunnel Pressure-Distribution Tests on an Airfoil with Trailing-Edge Flap. By Carl J. Wenzinger and Oscar Loeser, Jr. Technical Note No. 326. [A-1]

The six preceding Technical Notes listed were issued during October by the National Advisory Committee for Aeronautics, City of Washington.

Experiments with a Wing Model from Which the Boundary Is Removed by Suction. By Oskar Schrenk. Translated from Luftfahrtforschung, June 11, 1928. Technical Memorandum No. 534. [A-1]

Information Obtained from Airplane Flight Tests in the Year 1927-1928. By W. Hübner. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, April 29, 1929. Technical Memorandum No. 535. [A-1]

The foreging two Technical Memoranda were issued during October and November by the National Advisory Committee for Aeronautics, City of Washington.

(Continued on next left-hand page)

Notes and Reviews

Continued

Der Neue Flughafen München-Oberwiesenfeld. By K. J. Mossner, Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt,* Oct. 14, 1929, p. 493. [A-4]

Munich, as the second most important station on the Deutschen Lufthansa airways, occupying a strategic position for international commercial flying and special flights as well, merits an airport of the first order. This idea has guided the efforts of the author, who, in January, 1927, was commissioned by the City of Munich to start work on the proposed new airport.

Although Mr. Mossner consulted many articles on airport design, he found them for the most part too contradictory or too definitely applicable to some specific location to be of value to him. An exception was the outline of basic fundamentals issued by the German Government. His decision was to ignore precedent and to design for Munich an airport that would be adapted to the city's location and peculiar needs. He was obliged, because of the economic condition, to limit immediate construction to the demands that would be made on the airport at once, but his design provides for easy and generous expansion of the facilities to meet future growth in traffic. A detailed description, with plans, specifications and photographs, is given of the grounds, buildings and equipment.

Das Flugzeugkatapult auf dem Lloyddampfer Bremen. By B. Splanemann. Published in *Zeitschrift für Flubtechnik und Motorluftschiffahrt,* Sept. 14, 1929, p. 437. [A-4]

To facilitate postal service, the Bremen of the North German Lloyd line is equipped with a catapult apparatus from which an airplane leaves while the ship is still at some distance from her destination, carrying ahead the mail and customs papers.

In the detailed description set forth in this article, the fact is brought out that the catapult consists of a pivoted launching-way, a start skid, an accelerating and a testing contrivance. Some data of the catapult are: take-off speed, about 70 m.p.h.; accelerating distance, 65 ft.; braking distance for the skid, 10 ft.; total weight, with circular rail and pivot but without understructure, airplane and air compressor, about 25 tons.

Flying-Field and Airway Lighting. By H. R. Ogden. Published in the *Journal of the A.I.E.E.,* July, 1929, p. 555. [A-4]

In this paper the author discusses methods of lighting airports and airways and describes various types of lamps and equipment used for this purpose. In the information on airport illumination are included beacons, obstruction lights, boundary lights, illuminated wind-direction indicators, field and building floodlights, signal lights, and ceiling illumination. The portion on airway lighting covers principal and intermediate beacons and emergency-field lighting. The article is an abridgement of the original paper, which included an extensive bibliography.

Fire Prevention on Airplanes. By J. Sabatier. Translated from Bulletin Technique No. 56, of the Service Technique et Industriel de l'Aéronautique, January, 1929. Part I, Technical Memorandum No. 536; Part II, Technical Memorandum No. 537. Published by the National Advisory Committee for Aeronautics, City of Washington; 46 pp. each, illustrated. [A-4]

CHASSIS PARTS

Gear Geometry. By Allan H. Candee. Published in *American Machinist,* July 4, 1929, p. 17. [C-1]

In this paper, presented before the American Gear Manufacturers Association, the author declares he has collected and arranged his data with the idea of making the impor-

(*Continued on next left-hand page*)

Notes and Reviews

Continued

tant geometrical relationships as easy to see as possible, with the intention of providing a sound basis for a thoroughly logical and comprehensive system of gear geometry.

After developing a logical series of definitions for gear elements contained in a single plane of rotation, the author examines the third dimension in space geometry and gives tables for simplifying the practical application of the general case of an oblique involute rack to specific gear problems.

Part II of the article appeared in the July 11 issue.

Discussion sur la Suspension des Automobiles. By M. Messier. Published in *Journal de la Société des Ingénieurs de l'Automobile*, August, September, October, 1929, p. 763. [C-1]

The author, in formulating his theory of automobile suspension, conceives of it as possessing two flexibility factors. One he terms the rolling flexibility, which relates to oscillations around the longitudinal axis of the chassis; and the other, pitching flexibility, which relates to oscillations around the transverse axis. His experiments have led him to the conclusion that an automobile suspension should have the following five characteristics:

(1) Pitching flexibility variable with the severity of shock encountered, the curve representing such relation to be hyperbolic

(2) Automatic control designed so that, whatever the variations in the shock may be, the average distance between the axle and the chassis shall remain constant

(3) Rolling flexibility less than that of the pitching, following a straight-line relationship with the shock

(4) A shock-absorbing device which, while it permits the suspension to retain its sensitivity, opposes the creation of periodic oscillations, both of the chassis with relation to the axle and of the wheels with relation to the ground

(5) Horizontal connections that restrain all displacements from front to rear but leave vertical movements free to follow the curves laid down.

The system conceived to carry out these ideas, which is described in this article, is of a mixed character, being a combination of an automatically controlled pneumatic suspension and a mechanical anti-rolling device.

Brakes. By W. P. Kirkwood. Published in *The Automobile Engineer*, September, 1929, p. 349. [C-1]

The author has pointed out certain phases of the brake problem that have not been dealt with to any extent up to the present time and endeavored to indicate the general trend in design.

The possibilities of regenerative braking are considered in the case of the private passenger-car user in hilly country and the motorcoach which is required to make frequent stops. In the case of the latter, an accumulator which would absorb large quantities of energy for a short time is suggested.

Brake linings, the articulation of brake pull-rods, the effect of front-wheel brakes on steering, and ideal stopping distances are also considered briefly in the paper.

Le Récent Progrès des Boîtes de Vitesses pour Automobiles. By G. Delanghe. Published in *Le Génie Civil*, Aug. 31, 1929, p. 201. [C-1]

Two methods for securing the greater car flexibility necessitated by present congested traffic conditions are described and illustrated with examples of current constructions in this article on the recent progress in transmission design. The first method is the four-speed transmission, the fourth speed, for open-road running, being the direct

(Continued on next left-hand page)

Notes and Reviews

Continued

drive, and the third speed, for use in traffic, being designed especially for silent operation. The second method involves the retention of the conventional three-speed transmission with a supplementary gearbox between it and the rear axle.

In the first class are the Panhard-Levassor and the Mathis transmissions, in the former of which silent third-speed operation is obtained by the use of spiral gearing. The third-speed gears are constantly in mesh. The Mathis or Biflex transmission, also described, utilizes internal gearing for its third speed.

Of the second solution, two examples are described: the Voisin and the Berliet. The feature of the Voisin layout is that change from one to the other of the speeds in the secondary gearbox is made, not by the use of a gearshift lever, but through the action of manifold depression controlled by a handle on the instrument board. In the Berliet secondary gearbox one of the speeds corresponds to direct drive; the other furnishes the supplementary reduction through the use of internal gearing.

ENGINES

Oil-Engine Research at the University of Toronto. By Campbell Bradshaw. Published in *Power*, Sept. 3, 1929, p. 378. **[E-1]**

Convinced that the two-stroke-cycle oil engine is destined to become far more important commercially than it now is, Prof. E. A. Allcut, of the Department of Mechanical Engineering at the University of Toronto, has undertaken internal-combustion research on the Allen, an English engine of the hot-bulb type operating with crankcase compression.

Indicator diagrams and records of combustion pressures were taken at regular intervals and samples of exhaust gas were withdrawn into a gas holder having a capacity of 2 cu. ft., to be subsequently analyzed in a Burrell gas-analysis apparatus. The exhaust temperatures were taken with a chromel-copel thermocouple, and the cooling-water losses were found by weighing the water, the outlet temperature in all cases being kept, as nearly as possible, at 135 deg. fahr. The no-load test was made by removing the rope brake used during the other tests. The fuel used was a light fuel-oil.

Figures showing efficiencies, exhaust temperatures and engine loads; total fuel consumption and indicated load; and exhaust-gas analyses at various loads; give the results in graphical form.

Einfluss der Ventilatorenkonstruktion auf die Luftgeschwindigkeit durch den Autokühler. By J. Lipschitz, Published in *Automobiltechnische Zeitschrift*, Sept. 30, 1929, p. 596. **[E-1]**

The diversity in the size, shape and location of fans in automobile cooling-systems is a strong indication, asserts the author, that manufacturers have not given sufficient thought to this part of engine design to enable them to know and standardize on the most effective type.

In this and articles subsequently to be published, he recounts a series of tests to clarify this subject, made at the behest of the National Automobile Co. of Berlin. A preliminary investigation showed that the air velocity through a radiator is the determining factor in its cooling efficiency, hence this was selected as the criterion of fan performance. Power consumption was also measured. The elements of fan design investigated were the number of blades; inclination of blades to the radiator surface; curvature, length and width of the blades, and their distance from the radiator surface.

A detachable-blade fan, installed behind a radiator and driven by an electric motor, constituted the set-up for the tests. The radiator was marked off into nine squares and the air velocity through each square was measured at fan

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Notes and Reviews

Continued

speeds of from 500 to 2000 r.p.m. From these measurements an average value was calculated. This first article gives the results obtained with variations in the blade angle from 20 to 50 deg.

Neue Wege zur Verarbeitung Hochsiendender Kraftstoffe in Verpuffungsmotoren. By H. Ellerbusch. Published in *Automobiltechnische Zeitschrift*, Sept. 20, 1929, p. 571. [E-1]

An improved form of hot-plate has been developed to render possible the burning of heavy fuels in an internal-combustion engine. This plate is inserted in the combustion-chamber above the top position of the piston and parallel thereto. The liquid fuel is injected upon the hot-plate, through the opening in which the vaporized and ignited fuel flows to effect the power stroke of the piston. The opening has a diameter about 50 per cent of that of the piston. This opening is also placed near the exhaust side of the combustion-chamber to leave as large a vaporizing surface as possible adjacent to the incoming charge. The claims made for this form of hot-plate are that it will not burn out in use, that it makes possible clean and complete combustion of high-boiling-point fuels, and that an engine equipped with it will not consume any more heavy fuel per horsepower-hour than it would light fuel. Investigations to determine the most suitable metal to use, which embraced aluminum and forged and cast iron and copper, led to the selection of the last-named.

An improved form of inlet-manifold for use with heavy fuels was also developed.

Le Pétrole et la Force Motrice. By Paul Dumanois. Published in *Journal de la Société des Ingénieurs de l'Automobile*, July, 1929, p. 748. [E-1]

"In that merciless war which is peace," writes the author, who is technical director of the National Bureau of Liquid Fuels, "justice decrees that those nations will triumph which accord to science its rightful place." His address to the Society of Aerial Navigation is a plea that the scientists and engineers of France give earnest thought to searching out a new prime mover to displace the type of internal-combustion gasoline engine used today. In his opinion, this is unsuitable for aircraft from the standpoint of both safety and economy.

The author analyzes the present internal-combustion engine in a broad way, dwelling particularly on the limitation detonation places on its efficient functioning. He discusses various possible alternatives, most prominent among which is the Diesel engine. However, he envisions the real solution as an engine which is strictly of neither gasoline nor Diesel type, having the advantages of both and the disadvantages of neither; a high-speed, high-compression, mechanical-injection engine capable of burning heavy fuels.

That mechanical difficulties beset the development of such an engine he acknowledges, but as an inspiring example of how such difficulties can be surmounted he points to the German development of the Diesel engine. He urges that research and experiment be instigated in France so that, when the day of the mechanical-injection engine shall arrive, that country will have her own patents and not be merely a field for the exploitation of foreign licenses.

Retours au Carburateur. By Henri Petit. Published in *La Vie Automobile*, Sept. 10, 1929, p. 329. [E-1]

Back-firing in the carbureter, characterized as a frequent disturbance in the operation of automotive engines, follows always, at least in its later manifestation, the same line of action. At the moment when the inlet valve is opened, material at high temperature in the cylinder-head comes into contact with the fresh fuel-air charge entering from the manifold. This charge ignites and the flame spreads

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Notes and Reviews

Continued

throughout the manifold, causing a sharp increase in the volume of the gases, which escape by the only orifice open to them, the carbureter valve.

However, if the course of the back-firing is always the same, the cause is varied. Three possible roots of this evil are identified. The first is a mixture that is too lean and consequently burns so slowly in the cylinder that it is still in combustion when the inlet valve opens for the admission of a fresh charge. A number of deficiencies in carbureter action which may account for temporary impoverishment of the mixture, even when the setting is suitable for normal running, are pointed out. The second cause indicated is undue retardation of the spark. The heating of some point in the combustion-chamber to incandescence is the third cause analyzed. Having set forth the various causes, the author tells how the general phenomenon of back-firing can be diagnosed and traced to its true source.

Die Elektrische Ausrüstung des Kraftfahrzeuges; Teil II, Lichtmaschine und Batterie. By Alfred Mattes and Friedrich Trautmann. Published by M. Krayn, Berlin. 197 pp.; 164 illustrations. [E-1]

This book, which is one of three sections on the electrical equipment of automobiles, has for its field those parts that are the source of low-tension current: generators and batteries. The first section dealt with ignition, or high-tension current; the third, to appear later, will treat of the consumption of low-tension current. The series is part of an automotive technical library being issued by the publisher, and the present volume is technical in character with but little reference to current commercial construction.

The first chapter of the present book generalizes on the subject of low-tension current in automotive vehicles, touching on the historical aspects and the consumption demand made on generators. The theory of operation and the construction of generators take up the second chapter. Under the general heading of batteries, the chemical and electrical properties of storage batteries, their construction and, specifically, alkaline batteries are dealt with. Generator regulation, the construction of regulators and switches, and the installation and care of generators and batteries are other topics.

Inertia Torque. Published in *The Automobile Engineer*, September, 1929, p. 344. [E-1]

The author emphasizes the importance of the question of torque on the crankshaft resulting from the inertia of the reciprocating parts of an engine. The curves, which with the accompanying discussion form the major portion of the article, resulted from integrating the constants on the Institute of Automotive Engineers data sheets worked out by Mr. Kersey. The curves therefore give the relative torque for different types of engine having the same reciprocating weights and stroke; that is, the same size of cylinders. The power of the various types will therefore be proportionate to the number of cylinders. Curves are included in the paper for the four-cylinder vertical engine, the six-cylinder vertical engine, the straight-eight with cranks at 90 deg., the straight-eight engine with the four middle cranks in one plane and the end pairs at right angles, the eight-cylinder 90-deg. diagonal engine, the twelve-cylinder 60-deg. diagonal engine, and the twelve-cylinder broad-arrow engine.

HIGHWAYS

Effect of Wheel Type on Impact Reaction. By James A. Buchanan and E. G. Lapham. Published in *Public Roads*, July, 1929, p. 85. [F-1]

Other conditions being equal, cushioning material incorporated in the supporting structure of a motor-truck wheel reduces its impact reactions. This reduction may be negligible or important, depending upon the construction of the

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Notes and Reviews
Continued

wheel and the tire equipment used on it, according to the authors. The cushioning properties of cushion wheels become more pronounced as the cushioning properties of the tire equipment used on them decrease. The additional weight sometimes necessitated by cushion-wheel design may partly or even entirely offset the advantage gained by the cushioning action of the wheel structure insofar as the impact reaction on the pavement is concerned. For the conditions of the tests reported, observed tire deflections for impact pressures are virtually the same as those observed for static pressures of the same magnitudes.

These conclusions are reached as a result of an investigation made by the Bureau of Public Roads to determine the relative protective or cushioning quality inherent in different types of wheel. This project was part of the study being made by the Bureau concerning the general subject of motor-truck impact.

Normal equipment for a 2-ton truck was selected as being a fair basis for comparison. All known manufacturers of cushion wheels of this capacity were invited to submit wheels for test, but only two wheels of the cushion type were made available. These and a conventional wood-spoke artillery wheel were used in the program, and each was successively equipped with dual new cushions, dual new solid, and dual worn solid tires. For purposes of comparison, tests were also made on a pneumatic tire mounted on a rigid wheel. The method of test and the various instruments employed are described and illustrated, and the authors express the belief that the data given will be of value to wheel manufacturers and others interested in the development of cushioning devices for automotive equipment.

MATERIAL

Pinholes in Cast Aluminum Alloys. By N. F. Budgen. Published in *Engineering*, Oct. 4, 1929, p. 452. [G-1]

The small, variously shaped cavities or pinholes that sometimes look like black specks and are frequently seen in aluminum-alloy sand-castings are signs of unsoundness and often lead to porosity of castings. They occur mostly in sand-castings and are revealed either by machining or polishing. The author, in this paper presented before the Institute of Metals, at Dusseldorf, Germany, gives his observations of the phenomenon. The causes of pinholes are outlined; the formation of pinholes by gas evolution, their size, shape and dispersion are discussed; and the effects of ingot aluminum, melting and pouring temperatures, time the metal is maintained molten, and of the melting fuel and melting vessel and turbulent pouring are considered.

Aluminum and Its Alloys in Aircraft. By T. W. Bossert. Presented at the 56th general meeting of the American Electrochemical Society, Pittsburgh, September, 1929. [G-1]

The evolutionary stages of aircraft construction are outlined by the author, who attributes the widespread adoption of metal construction in aircraft to the availability of aluminum alloys having the strength of structural steel but only one-third its weight. The properties of these alloys are outlined and characteristic examples of their application are described and illustrated.

Other papers of interest presented at the same meeting include the following four:

Magnesium and Its Alloys in Aircraft. By W. G. Harvey. [G-1]

The author tabulates the mechanical properties of magnesium alloys and discusses the fabricating obstacles that have been overcome. The resistance to corrosion and the comparatively high mechanical strength of forgings are also noted.

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Notes and Reviews

Continued

The Possible Use of Beryllium in Aircraft Construction. By H. W. Gillett. [G-1]

The physical properties of beryllium are briefly reviewed. An outstanding property is the high modulus of elasticity, which is nearly three times that of magnesium. Beryllium is more abundant in the earth's crust than either lead or zinc. The probable future development and application of the metal are discussed at length, and the author concludes that beryllium will some day be an important factor in aircraft construction.

Thermo-Electric Tests for Aluminum-Manganese and Other Alloys. By Cyril S. Taylor and Junius D. Edwards. [G-1]

Solution Potentials of Aluminum Alloys in Relation to Corrosion. By Junius D. Edwards and Cyril S. Taylor. [G-1]

Effects of Knock-Suppressing and Knock-Inducing Substances on the Ignition and Partial Combustion of Certain Fuels. By Raymond E. Schaad and Cecil E. Boord. Published in *Industrial and Engineering Chemistry*, August, 1929, p. 756. [G-1]

Hot-wire-ignition curves were determined for toluene, isoamyl acetate, and kerosene between the lower and upper limits of inflammability. The fuel-air mixtures investigated were produced by a vapor-pressure method which is described and shown to be applicable to the continuous and reproducible preparation of such a series of mixtures.

The current required by an electrically heated platinum wire for ignition of the most easily ignitable mixture of air and toluene, isoamyl acetate, or kerosene was increased by the addition to the fuel of a knock suppressor such as lead tetraethyl or selenium diethyl. On the contrary, the addition of one of the knock inducers decreased the hot-wire ignition current.

The knock suppressors and inducers used in this work had no noticeable effect on the ignition curves obtained for toluene, isoamyl acetate, and kerosene by means of direct-current break sparks.

The Measurement of Detonation in Internal-Combustion Engines. By R. O. King and H. Moss. Published in *Engineering*, Aug. 23, 1929, p. 219. [G-1]

In this article the authors discuss the economy of increasing compression ratios which require an increase in the antiknock properties of fuels that involves greater cost of the fuel to the consumer. Various methods of measuring detonation now in common use in America and England are described and the consistency and sensitivity of results compared.

The experiments described were conducted for the most part in the Air Ministry laboratory at the Imperial College of Science, South Kensington. In addition, data are given for tests made by S. D. Heron at the Ethyl Gasoline Corp. in this Country with the assistance of the staff of the Anglo-American Oil Co. The equipment in the two laboratories was similar.

Welding Rustproof Steels. By W. Hoffmann. Translated from *Autogene Metallbearbeitung*, Dec. 15, 1927, vol. 20. Technical Memorandum No. 531. Published by the National Advisory Committee for Aeronautics, City of Washington; 9 pp., 18 figures. [G-5]

Welding of Stainless Materials. By H. Bull and Lawrence Johnson. Reprinted from *Industrial Gases*, March and June, 1928. Technical Memorandum No. 532. Published by the National Advisory Committee for Aeronautics, City of Washington; 37 pp., 30 figures. [G-5]

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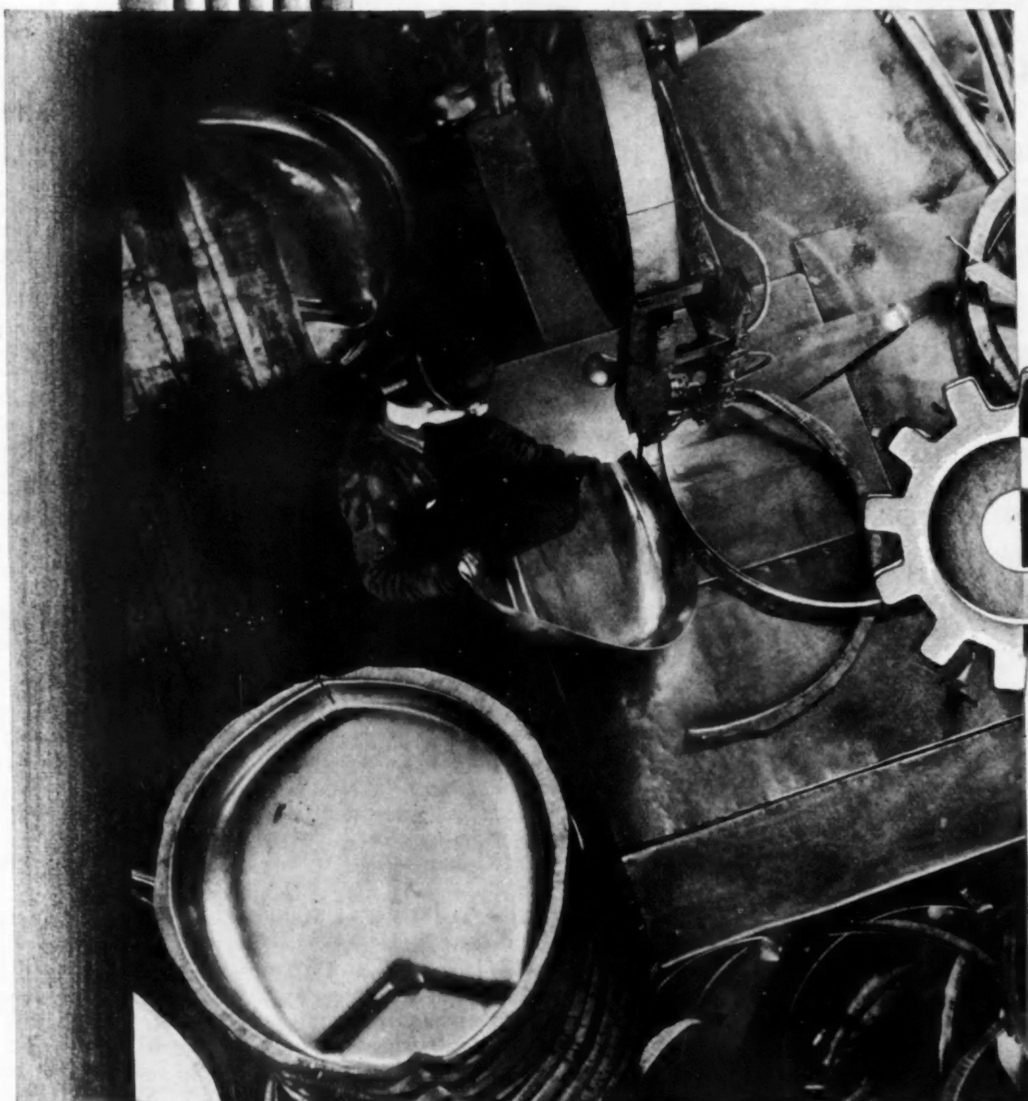

Notes and Reviews

Continued

The Case-Hardening of Carbon Steel for Automobile Purposes. By H. Swain. Published in *The Automobile Engineer*, June, 1929, p. 226. [G-5]

An historical sketch of the early uses and principles of case-hardening and the characteristics of carbon steels are given in this article. The methods of case-hardening are discussed and the usual faults and how to detect and eliminate them are also covered, with a concluding section on hardness testing.

Deutsche Kraftstoffe. By Herbert Bahr. Published in *Automobiltechnische Zeitschrift*, Aug. 31, 1929, p. 521. [G-5]

In Germany, as in all countries which largely import petroleum products, the development of domestically available gasoline substitutes is a question not alone of abstract theoretical interest but of prime economic significance. Its importance from the viewpoint of Germany's national trade balance may be gaged from the fact that her imports of gasoline in 1928 amounted to the value of 123,000,000 marks.

This article canvasses the field of substitute motor-fuels, outlining the various chemical researches to this end, indicating their present practical importance and estimating their probable future significance, dwelling particularly on the interest to Germany of a domestic fuel-supply. The status of this question in countries outside of Germany is also outlined.

Synthetic liquid fuels produced by various types of hydrogenation process are dealt with first. The methods developed by Bergius, the I. G. Farbenindustrie and Fischer and Tropsch are principally referred to. Warning against counting too strongly on such fuels for the immediate present, the author cites the fact that, of the total German motor-fuel consumption in 1928, only about 10 per cent was produced synthetically.

After recounting the various efforts made to put on the market a motor fuel in which alcohol is an important constituent, Herr Bahr concludes that at present alcohol does not play an important part as a motor fuel because of its high production cost. The situation as regards benzol and detonation suppressors is also surveyed.

As to the future, the author concludes that it is only a question of time until the production of synthetic fuels will be adequate to supply home consumption. Germany, he feels, is fortunate in being the pioneer in the production of gasoline substitutes and may achieve in this field the success of the saltpeter industry. Saltpeter was formerly imported in large quantities by Germany, but is now exported.

The Production and Uses of Helium Gas. By R. R. Bottoms. Published in *Mechanical Engineering*, September, 1929, p. 663. [G-5]

This article is an abridged copy of the original paper covering the origin and occurrence of helium, the quantity available, its production, storage and transportation, and a discussion of the special problems connected with the use of helium in airships.

Helium was first discovered as a terrestrial element in 1895 by Sir William Ramsay. It belongs to the group of elements known as the rare gases of the atmosphere. Years of research, following Ramsay's discovery, the author states, resulted in information concerning its occurrence in small amounts as a constituent of the atmosphere, of gases from mineral springs, of volcanic gases, and in small quantities in sea water.

Misgivings regarding the amount of helium available for airship use are dispelled by the estimate of a total of 10,000,000,000 cu. ft. of helium available in the United States, located principally in Colorado, Kansas and Texas.

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Notes and Reviews

Concluded

The complete paper, which will appear in the *Transactions of the A. S. M. E.*, Aeronautic Division, it is said, contains descriptions and schematic drawings of helium producing plants.

MISCELLANEOUS

Personnel Service Leaflet. Published by the Personnel Office of the Division of Engineering, Iowa State College, Ames, Iowa. **[H-3]**

With the cooperation of the Engineering Student Council, this leaflet has been published for the senior engineers of the nine departments of the Engineering Division. It is composed of loose leaves, each showing a half-tone print of the student, and giving a statement of his major interests, college activities, experience, and the date on which he expects to be available to take an engineering position. The leaflets are distributed to the leading industries and kept uptodate by means of inserts and refills supplied from time to time. The leaflets for the class of 1930 will be available Jan. 1, 1930, it is announced, and will be sent to companies which signify their interest.

1929 Supplement to Book of A.S.T.M. Standards. Published by American Society for Testing Materials, Philadelphia; 293 pp. **[H-3]**

The 1929 Supplement to the 1927 edition of the triennial publication, Book of A.S.T.M. Standards, is now available. It contains 19 revised and 32 newly adopted standards. The standards relating to metals and to non-metallic materials appear in the one pamphlet, thus making it supplementary to both Part I, Metals, and Part II, Non-Metals, of the 1927 Book of Standards.

PASSENGER CAR

Der Stoewer-Achtzylinder-Wagen. By Victor Conrad. Published in *Automobiltechnische Zeitschrift*, Sept. 10, 1929, p. 543. **[L-1]**

A thorough examination of the Stoewer eight-cylinder car is made in this article. The first part describes the constructional features; the second part, to appear later, will deal with the performance of the car.

The eight-in-line cylinders are cast in one piece with the crankcase. The crankshaft, which has babbitted bearings, is provided with a vibration dampener. A specially developed form of cam is said to give smooth valve operation. The cylinder-head is removable and the combustion-chamber space was designed for turbulence. The crankcase is ventilated.

Some of the chassis features are: a four-speed transmission; four-wheel Ate-Lockheed brakes; springs embedded in rubber cushions, and rubber engine-mounting.

Strukturuntersuchungen an Drei Kleinwagen. By E. Friedlaender. Published in *Automobiltechnische Zeitschrift*, Sept. 30, 1929, p. 593. **[L-1]**

Tests made of three light cars of German manufacture, the BMW, the DKW and the Hanomag, are recorded in this article. The elements of performance investigated were acceleration from a dead stop to 60 km. per hr. (37.28 m.p.h.), allowing free choice of the most suitable speed, and acceleration from 10 to 60 km. per hr. (6.214 to 37.28 m.p.h.) in high speed. From the results of the latter, deductions confirmed by actual trial are made as to the hill-climbing ability of the three cars. Roughly, the time consumed by them varied, for the first test, from about 29 to 33 sec., and for the second, from 39 to 49 sec.

The advance of the light car to the foreground of importance is asserted by the author to be the most notable development in the German automotive industry in the 11 years since the close of the war; a sound development justified by economic conditions.

Personal Notes of the Members

(Continued from p. 693)

Mr. Lítle has long been prominent in the design and manufacture of high-class motor-cars. In 1917 he formed a connection with the Cadillac Motor Car Co., and the following year joined the Lincoln Motor Co. as engineer. In 1920 he was appointed research engineer and two years later research experimental engineer of the Lincoln company. He was promoted to chief engineer of the Lincoln Division of the Ford Motor Co. in 1924 and remained with that organization until, in 1926, he established himself as engineering production consultant in Detroit, prior to his affiliation with the Marmon company.

Elected to Membership in 1919, Mr. Lítle has since then been very active in the affairs of the Society. He was Secretary of the Detroit Section in 1922 and its Chairman during 1923, when he acted also as a member of the Society's Research Committee, as he also did the following year. In 1925 he was on the Hardwood Lumber Standardization and the Motor-Vehicle Lighting Specifications Committees, and held the position of First Vice-President of the Society.

The following year, while President of the Society, Mr. Lítle was a member of the following committees: Nonferrous Metals Division and Tire and Rim Division of the Standards Committee, Research Committee, Headlight and Riding-Qualities Subcommittee of the Research Committee, and Special Committee on Standardization Policy. He also was Chairman of the Advisory Committee on Automobile Locks. In 1927 he served as Councilor and on the Riding-Qualities Subcommittee, as well as on the Special Committee on Standardization Policy. During 1928 he was, in addition to the aforementioned, a member of the Publication Committee and the Motor-Vehicle Lighting Specifications Committee. At present he is active in the following Committees: Standardization Policy Committee, Stock-Car Contest Advisory Committee, Riding-Qualities Subcommittee, Motor-Vehicle Lighting Specifications Committee, and Tire and Rim Division of the Standards Committee.

Templin Now Serving Chrysler Corp.

After having had charge, for more than a year, of the fleet of motor-trucks operated by the Mavis Bottling Co. of America, E. W. Templin has become connected with the Chrysler Corp. In his new position he is responsible for the interplant motor transportation system of the company, which involves about 150 trucks.

Mr. Templin, who has been a Member of the Society since 1918, was elected Councilor for the term of 1928 and 1929. He is also a member of the Motorcoach Division of the Standards Committee and member-at-large of the Sections Committee. A Personal Note reviewing his business career and earlier activities in the Society was published in the August, 1928, issue of the S.A.E. JOURNAL.

Meister Made Assistant General Manager

H. O. K. Meister has been appointed assistant general manager of the Hyatt Roller Bearing Co., located at Newark, N. J. His connection with Hyatt dates back to 1915, when he joined the company in the capacity of assistant advertising manager, just after relinquishing the position of draftsman with the Allis-Chalmers Co., of Milwaukee, with which he had been associated during the first seven years of his experience in the engineering field.

In the second year of his association with the Hyatt company he was made sales manager of the tractor bearings division. In 1923 he assumed the management of the western division, but two years later returned to the Harrison, N. J., plant as assistant general sales manager. After two more years he was advanced to the post of general sales manager, which he held until his recent appointment as assistant general manager.

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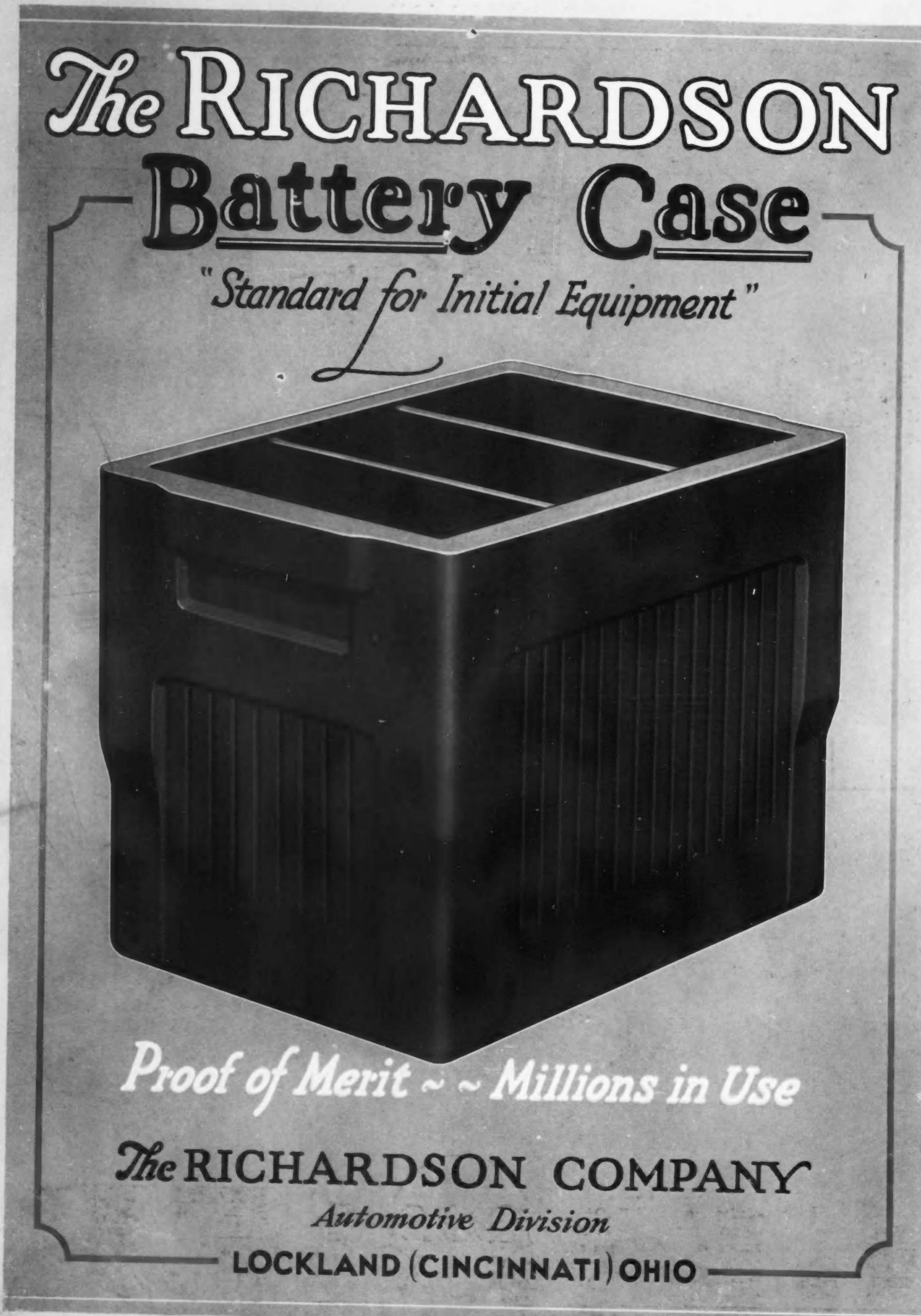
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Personal Notes of the Members

Continued

Mr. Meister was elected a Member of the Society in 1918 and since that time has taken an active part in National and Section work. He joined the Mid-West Section, later called the Chicago Section, in 1922, and served two terms as Secretary of that Section, but transferred his affiliation in 1927 to the Metropolitan Section. In 1924 he was elected a member of the Sections Committee of the Society, and in 1926 served as a member of the National Meetings Committee.

Zucrow Joins Paragon Vaporizer Corp.

Maurice J. Zucrow, who has been research assistant and research associate in hydraulic and carbureter work at the Purdue University engineering experiment station in Lafayette, Ind., since being graduated in 1923 from the Harvard Engineering School with the degrees of bachelor of science and master of science, and who received the degree of doctor of philosophy from Purdue University in 1928, has joined the Paragon Vaporizer Corp., of Chicago, as research engineer.

Dr. Zucrow was elected a Member of the Society early in 1926 and joined the Indiana Section soon afterward. He contributed a paper on Distribution in Multi-Cylinder Engines at the Mixture-Distribution Conference at the Summer Meeting this year. This paper was published in the October number of the S.A.E. JOURNAL, p. 398. He is the author of various other papers and reports on carbureters and hydraulic subjects published in Purdue University bulletins, the *Engineering News-Record, Power, Power Plant Engineering,* and the *Journal of the American Water Works Association.*

Youngren Now with Buick

Harold T. Youngren has announced his resignation as executive engineer of the Studebaker Corp. of America to become associated with the Buick Motor Co., of Flint, Mich., in the capacity of assistant chief engineer.

In the early part of his engineering experience Mr. Youngren engaged in drafting and designing for various companies. He entered the service of the Pierce-Arrow Motor Car Co. in 1920, and two years later was appointed chief draftsman. He continued in this position until 1927, when he joined the Studebaker Corp. as designing engineer. In the following two years he was successively made consulting engineer and executive engineer.

Mr. Youngren became a Junior Member of the Society in 1912 and in 1921 was transferred to Member grade. He joined the Buffalo Section in 1920 and has been an active participant in National and Section affairs. In 1924 he served as Treasurer of the Buffalo Section; in 1925, as Secretary, and in 1926, as Chairman.

George B. Allen was recently advanced from the position of chief engineer to that of director of engineering of the Detroit factory of the Dodge Brothers Corp.

Thomas Backus is now acting in a designing capacity for the Caterpillar Tractor Co., of San Leandro, Calif. Prior to forming this connection he was engineer for the Willys-Overland Co., at Toledo.

Carl Bailys, until recently a student engineer in the die department of the Ford Motor Co., has joined the Michigan Copper & Brass Co., in Detroit, in the capacity of chemical engineer and metallurgist.

Frederick O. Ball, former president and general manager of the Ball & Ball Carbureter Co., of Detroit, has relinquished his position to become a research engineer for the Chrysler Corp., also of Detroit.

George C. Bauer has accepted a position as draftsman with the Chance Vought Corp., of Long Island City, N. Y.

(Continued on next left-hand page)

Personal Notes of the Members

Continued

George E. Bechtel has joined the Trundle Engineering Co., of Cleveland, as a staff engineer.

C. C. Bowman, associated with the Standard Motor Truck Co., of Detroit, has been advanced from the post of chief engineer to that of general sales manager of that company.

Arthur J. Brandt has severed his connection as consulting industrial executive with the Autocar Co., of Ardmore, Pa., to enter the independent field as consulting and management engineer, with offices in Detroit.

Fred G. Bremer recently entered upon his new duties as sales manager and sales engineer with the Bay City Foundry & Machine Co., of Bay City, Mich.

Jay Robert Brown was recently appointed assistant production manager with the Thew Shovel Co., of Lorain, Ohio. His previous connection with the company was that of production engineer.

Donald J. Bullock has left the independent field to enter the employment of Gazley & LaSha, consulting aeronautical engineers, of the City of Washington.

First-Lieut. Samuel S. Burgey, of the Ordnance Department of the Army, has been transferred from his previous station at Fort Bliss, Texas, and is now adjutant at the Watertown Arsenal, at Watertown, Mass.

Harold Caminez, formerly chief motor engineer of the Allison Engineering Co., of Indianapolis, has been transferred by the General Motors Corp. and is now engineer in charge of the aircraft-engine division of the Cadillac Motor Car Co., of Detroit.

George C. Carhart, former clutch and transmission engineer with the Buick Motor Co., of Flint, Mich., has been advanced to the post of research engineer with that company.

Gustave Chutorash, until recently assistant to the body engineer of the Fisher Body Corp., of Detroit, has been advanced to the post of chief engineer.

Ronald Clark, previously managing director of the Societe Anonyme Francaise, North East, Paris, France, has relinquished that post to enter upon some special work for the General Motors Export Co.

Louis S. Clarke has sold his interest in the Autocar Co., of Ardmore, Pa., and retired. Mr. Clarke organized the Autocar Co. in 1897, and at the time of his retirement was vice-president and consulting engineer of that company.

Thomas A. Clarke, formerly manager for Dutee W. Flint, of Pawtucket, R. I., has relinquished his post to join W. P. Hamblin, Inc., of Providence, R. I., as wholesale manager.

Franz W. Cook has joined the Johnson Carbureter Co., of Detroit, as sales engineer. His previous connection was with the Chevrolet Motor Car Co., of Detroit, for which he was in charge of dynamometers in the experimental department.

P. L. Crittenden, former chief engineer with the National Brake & Electric Co., of Milwaukee, has been made vice-president and general manager of that company.

J. Edward Dagenais has joined the Ford Motor Co. of Canada, Ltd., in Montreal, as service organizer.

E. H. Delling, who has been chief engineer of Brooks Steam Motors, of Buffalo, for the last four years, has resigned this position to seek financial backing for the building of a new type of steam motorcoach.

E. R. Doody has assumed the duties of sales manager for Herbert McLean Purdy & Co., of New York City. His previous connection had been with the General Motors Truck Co., in New York, where he served as service supervisor.

Edmund U. Fairbanks, until lately a junior mechanical engineer at the Naval Aircraft Factory in Philadelphia, has joined the Glenn L. Martin Co., in Baltimore, as an engineer.

(Continued on next left-hand page)

Personal Notes of the Members

Continued

N. A. Finch, Jr., is now sales engineer in the truck and bus division of the General Motors Export Corp., of New York City. His previous connection was as vice-president and general manager of Rowland Transportation, Inc., of Franklinville, N. Y.

Eugene W. Field has left the Western Oil Refining Co., of Indianapolis, for which he was assistant general sales manager, and is now president of the Mid-Western Petroleum Corp., also of Indianapolis.

Milton E. Fisher is now superintendent of maintenance for the Morris Draying Co., of Oakland, Calif. He was previously production manager of the company.

H. Torrey Foster, who until recently was research statistical engineer of Thompson Products, Inc., in Detroit, has been advanced to the post of assistant to the general manager of the Detroit plant of that company.

Carl B. Frevert, a former engineer with the Hart-Parr Co., of Charles City, Iowa, has joined the Oliver Farm Equipment Co., of that city, in the same capacity.

Robert Gaylord has been elected to the presidency of the Ingersoll Milling Machine Co., of Rockford, Ill. He formerly held the position of vice-president of that company.

Alva B. Gilbert, previously identified with the Ford Motor Co., of Detroit, as a draftsman in the airplane engineering department, has severed this connection to become a draftsman with the Chrysler Motors Corp., of Highland Park, Mich.

Phillip P. Glick, who was erroneously reported in the November issue of the S.A.E. JOURNAL as having left the Moon Motor Car Co. to become connected with the Gardner Motor Co., of St. Louis, has not joined the latter organization. Instead, his new connection is in the capacity of production supervisor with New Era Motors, Inc. His headquarters, however, are at the factory of the Gardner Motor Co., where the first Ruxtons, front-wheel-drive vehicle of the New Era firm, are being built on contract.

Walter A. Graf, associated with the Edward G. Budd Mfg. Co., of Philadelphia, has been advanced from the post of foreign service engineer to that of director of foreign engineering.

Walter Grothe, associated with the Caterpillar Tractor Co. of San Leandro, Calif., as engineer in charge of steel treating, has been appointed chief metallurgical director of the company.

Leo V. Grogan has given up his position as estimator in the sales department of the Forest Park Electric Co., of Springfield, Mass., to become operating engineer with the Linde Air Products Co., of Niagara Falls, N. Y.

Joseph W. Grumme, Jr., formerly a development engineer with the New York Air Brake Co., of Watertown, N. Y., has been made superintendent of the carrier division of that company.

J. F. Guider has resigned as works manager of the Pierce-Arrow Motor Car Co., of Buffalo, to become vice-president and engineer in charge of sales for the J. L. Osgood Machinery & Tool Co., Inc., also of Buffalo.

Donald Landmann Hague is now a student engineer with the New Jersey Bell Telephone Co., of Newark, N. J.

Clarence M. Hartnett has announced his connection with the Dairy Delivery, Inc., of San Francisco, as superintendent of motor-vehicles.

Walter M. Hartung was recently appointed design engineer for the Aircraft Improvement Corp., of New York City. His former connection was with the Skyward Aircraft Co., of Brooklyn, for which he served as aeronautical engineer.

Richard W. Hautzenroeder, whose post with the W. A. Riddell Co. of Bucyrus, Ohio, until recently was that of designer and assistant to the chief engineer, is now chief designer of the crawler engineering department.

(Continued on next left-hand page)

Personal Notes of the Members

Continued

Arthur J. Hazen has been made assistant chief engineer with the Kissell Motor Car Co., of Hartford, Wis. Before this appointment he was chief draftsman.

Ronald M. Hazen is now assistant chief engineer with the Fairchild Engine Corp., of Farmingdale, N. Y. His previous connection with the company was that of assistant chief powerplant engineer.

Earl A. Hecht, until lately associated with the Columbus Tire & Rubber Co., of Mansfield, Ohio, has joined the Westinghouse Electric & Mfg. Co., also in Mansfield, as layout engineer.

John Hirtreiter, until recently an engineer with the Wisconsin Motor Co., of Milwaukee, has recently joined the Elto Division of the Outboard Motors Corp., also of Milwaukee, as engineer.

Sidney M. Hunn has become identified with the American Aeronautical Corp., of Port Washington, L. I., N. Y. His previous connection was with the Fairchild Airplane Mfg. Corp., of Farmingdale, N. Y., with which he served in the production department.

Donald R. Husted has left the independent field and is now with the General Development Co., Inc., of New York City, as aeronautical engineer.

W. T. Jacobs, formerly factory manager for the Henney Motor Co., of Freeport, Ill., has been put in charge of the engineering department of that company.

Alexis B. Kononoff, a former student at the Massachusetts Institute of Technology, has been engaged by the Buick Motor Co., of Flint, Mich., as student engineer.

Milton J. Kittler, until recently a student in the Armour Institute of Technology, in Chicago, has entered the service of the International Harvester Co., as a junior engineer in the experimental department.

A. J. Larkin has severed his connection as service engineer with the Heywood Starter Corp., of Detroit, and is now with the Sky Specialties Corp., of that city, in a similar capacity.

Thomas J. Leary is now sales manager of Motors & Boats, Inc., of Chicago. His former connection was with the Biflex Products Co., of Chicago, as branch manager.

Edward Lester, formerly shop superintendent of the Shell Oil Co. of California, has been made district supervisor at that company's Seattle, Wash., branch.

Francis J. Linke has announced his connection with the American-LaFrance & Foamite Corp., of Elmira, N. Y., as delivery engineer.

W. C. Mackenzie has been appointed chief engineer of the Standard Motor Truck Co., of Detroit. He was formerly chief engineer of the Acme Motor Truck Co., of Cadillac, Mich.

Albert H. Maggs, a former designing engineer with the Ahrens-Fox Fire Engine Co., of Cincinnati, has been made assistant chief engineer with that company.

J. A. Mahoney has entered the sales division of the Waukesha Motor Co., of Waukesha, Wis., having before been division engineer with the Vacuum Oil Co., of Milwaukee.

Kingsley Gould Martin has been made assistant general manager of the Frank Presbrey Co., of New York City, for which he was formerly account manager.

Loyal D. McWhirter now has charge of motor rebuilding for the Thompson Motor Co., of Beverly Hills, Calif. He previously held a similar position with the Lynn C. Buxton Co., also of Beverly Hills.

James L. Meyers, until recently chief engineer of the Cleveland Graphite Bronze Co., of Cleveland, has recently been elected secretary of the company.

Curtis C. Miller, a former layout designer with the Hupmobile Motor Car Co., of Detroit, is now a sheet metal design and layout draftsman with the Hudson Motor Car Co., also of Detroit.

(Continued on next left-hand page)

Personal Notes of the Members

Continued

Chester E. Mines, a former student of mechanical engineering at the University of Florida, recently joined the Cadillac Motor Car Co., of Detroit, as a junior mechanical engineer.

Courtney Mitchell has recently joined the Cleveland Door Check Mfg. Co., of Cleveland, in the capacity of chief engineer.

Orin Moe, formerly chief engineer with the Moreland Aircraft Co., of Los Angeles, has severed his connection with that company to enter the employment of the Stearman Aircraft Co., at Wichita, Kan.

Chester Sherman Moody, associated with the Killefer Mfg. Corp., of Los Angeles, was recently made superintendent of that company. His former post was that of metallurgical engineer.

Francis Rider Moore, until recently engineering draftsman with the Detroit Airplane Co., of Detroit, has been made designer and draftsman with the Detroit Aircraft Co., in the same city.

Clinton E. Morgan has been elected president of the Cincinnati Car Corp., of Cincinnati. He was formerly vice-president and general manager of the Brooklyn City Railroad, of Brooklyn, N. Y.

William A. Morgan has relinquished his position as service manager with Roach & Dixon, Inc., of Los Angeles, to accept a position as sales manager of service with James L. Dixon, Inc., also of Los Angeles.

Charles A. Morrow has become identified with the Chevrolet Motor Co., of Flint, Mich. He is a former student of the General Motors Institute of Technology.

Cammille P. Morvan, who until recently was a body designer for the Packard Motor Car Co., of Detroit, has joined the Andre Citroen Co., also of Detroit, as engineer.

C. E. Murray has been transferred from the Chicago office of the Willard Storage Battery Co., where he served as district manager for manufacturers sales, to the offices of the Canadian company located at Toronto, and advanced to the post of vice-president and general manager.

G. Harold Norberg, formerly mechanical engineer with the Continental Tool Works, of Detroit, recently severed his connection with that company to enter the employment of the Swedish Gage Co. of America, also located in Detroit, as manager.

Eric Nygard, formerly instructor in civil engineering at Union College, Schenectady, N. Y., has recently become identified with the International Motor Co., of Allentown, Pa., as experimental engineer.

Thomas A. O'Connor, now territory supervisor for the Nash Breyer Motor Co., of Los Angeles, was formerly sales manager of the Vermont Nash Co., of Los Angeles.

Ernest V. Pannell, now associated with the London Aluminum Co., Ltd., of Birmingham, England, in the capacity of manager, was previously consulting engineer of the British Aluminum Co., Ltd., in New York City.

Benjamin G. Parsons, who until recently was chief engineer of the Hurricane Motor Co., of Houston, Texas, has assumed a similar position with the Hurricane Aviation Corp., also of Houston.

C. H. Paulsen has joined W. T. Roberts, Inc., of Boston, in the capacity of manager of the industrial dryer and dry-kiln department.

Pierre B. Pendill has resigned as automotive engineer with the American Car & Foundry Motors Co., of Berkeley, Calif., to assume similar duties with the C. H. Will Motors Corp., of Oakland, Calif.

Clifton Reeves, until lately head of Clifton Reeves & Associates, industrial engineers, has entered upon new duties as vice-president and industrial engineer for the Mullins Mfg. Co., of Salem, Ohio.

Harry J. Richards has recently become vice-president of

(Continued on next left-hand page)

Personal Notes of the Members

Continued

the Larrabee-Deyo Motor Truck Co., of Binghamton, N. Y., of which he was chief engineer.

Hans Rose, until lately associated with the Horace T. Potts Co., of Philadelphia, as sales engineer, is now metallurgist for the Fokker Aircraft Corp., at Hasbrouck Heights, N. J.

Raymond Hugh Rose, formerly chief engineer with Guy Motors, Ltd., of Wolverhampton, England, has entered upon new duties with the Sunbeam Motor Car Co., Ltd., also in Wolverhampton.

William C. Rosenthal has given up his post as assistant engineer of the package-car division of the Mechanical Mfg. Co., of Chicago, to become an engineer in the tractor works of the International Harvester Co., also in Chicago.

F. W. Sampson has severed his connection with the Continental Motors Corp., of Detroit, where he served in the capacity of engineer in charge of shock-absorbers, to enter the employment of the Inland Mfg. Co., of Dayton, Ohio.

William D. Sargent, former president and treasurer of the Eastern Steel Castings Co., of Newark, N. J., has been elected president of Vulcan Wheels, Inc., also of Newark.

R. I. Schneitzer was recently placed in charge of body engineering for the Auburn Automobile Co., of Auburn, Ind. His previous connection was with the Truscon Steel Co., of Cleveland, as chief engineer.

Walter M. Scott has been elected president of the Sterling Mfg. Co., of Cleveland. He is also general manager of the company, and until recently was its secretary and treasurer.

F. P. Servais has relinquished his position as engineer with the Chrysler Corp., of Detroit, to become research engineer with the Silent Bloc Co., Inc., also of Detroit.

E. Sherrick, who is now a designer with the Detroit Aircraft Co., in Detroit, was formerly a draftsman of motor-car chassis layout with the Cadillac Motor Co.

Stanley E. Sherriff, a former automotive engineer with the Schulze Baking Co., of Kansas City, Mo., has been made superintendent of delivery equipment with that company.

Bruno M. Smiling has been made assistant executive engineer and chief draftsman with the Sikorsky Aviation Corp., of College Point, N. Y. Prior to this advancement, he was assistant chief draftsman with that company.

E. H. Smith, formerly experimental engineer for the Olds Motor Works, at Lansing, Mich., has been advanced to the post of assistant chief engineer with that company.

Herschel G. Smith is now manager of refinery technology for the Gulf Refining Co., of Port Arthur, Texas. His former title was that of superintendent of research and refinery technique.

Elwood G. Soash, a graduate of Ohio State University, recently entered the service of the Toledo Machine Tool Co., Toledo, Ohio.

John Squires, until lately president of the Kreider-Reisner Aircraft Co., Inc., of Hagerstown, Md., is now president of Air Propellers, Inc., also of Hagerstown.

A. Ralston Stalb has been made manager of the pontoon department of the Aircraft Products Corp., of Detroit. He was formerly chief engineer of the metal-boat division of the Fairchild Airplane Corp., of Farmingdale, L. I.

Fred W. Stein is now the director of inspection for Fairbanks, Morse & Co., of Beloit, Wis. Previously he was on the staff of the vice-president of manufacturing of that company.

Bernhard Stern, who was serving the Chrysler Corp., of Detroit, as assistant to the standards engineer, has been advanced to the post of experimental engineer.

Herman Stoll has accepted a position as research engineer with the firm of Adam Opel, A.G., Russelsheim on Main, Germany.

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Personal Notes of the Members

Concluded

Theodore Taylor has relinquished his post as transportation manager for the Rubel Coal & Ice Co., of Brooklyn, N. Y., and become superintendent of rolling stock for Stern Brothers, of New York City.

Henry H. Thompson has been transferred from his post as general engineer of aviation activities with the Westinghouse Electric & Mfg. Co., to that of aviation engineer in the general engineering department at East Pittsburgh, Pa.

Robert L. Thuner, formerly sales manager for the O. & S. Bearing Co., of Detroit, has been made vice-president and director of sales for that company.

Arthur D. Tiel, who for a number of years was service manager for the Autocar Co. of Pittsburgh, has severed his connection with that company and is now acting in a similar capacity for the Sterling Motor Truck Co., also of Pittsburgh.

Sam Tour, former vice-president of Lucius Pitkin, Inc., of New York City, has also been made chemical and metallurgical engineer with that company.

T. Johan Uilkema, until recently lubricating engineer with the Sinclair Refining Co., of Chicago, has become a designing engineer with the General Motors Corp., of Detroit.

Theodore M. Van der Stempel, a former engineer on the staff of the *Electric Railway Journal*, in New York City, has been made assistant editor of that publication.

W. Robert Vogeler has been elected president of the Mercedes-Benz Co., Inc., of New York City. His former title was vice-president and general manager.

Hubert Walker recently became chief engineer of the American-LaFrance & Foamite Corp., of Elmira, N. Y. He previously served this company in the capacity of assistant chief engineer in charge of production and development.

A. A. Warner, sales manager of the Universal Products Co., of Dearborn, Mich., has also been made chief engineer of that company.

Horace E. Weihmiller, formerly general manager of his own company, is now president of the Carman Aircraft Corp. of Delaware, with headquarters in Dayton, Ohio.

Adrian E. Weiss, who has been associated with the Superior Die Casting Co., of Cleveland, as factory manager, has been made secretary of that company.

Edwin A. Weiss has become connected with the Willys-Overland Co., of Toledo, in the capacity of assistant engineer in the engine and chassis division.

Lester E. Wetzler is now layout draftsman on gasoline engines with the Climax Engineering Co., of Clinton, Iowa. He was formerly designer of methyl-chloride refrigerators for the A. A. Wickland Co., Inc., of Chicago.

David R. Wilson has been elected president and general manager of the Wilson Foundry & Machine Co., of Pontiac, Mich., having previously been vice-president of that company.

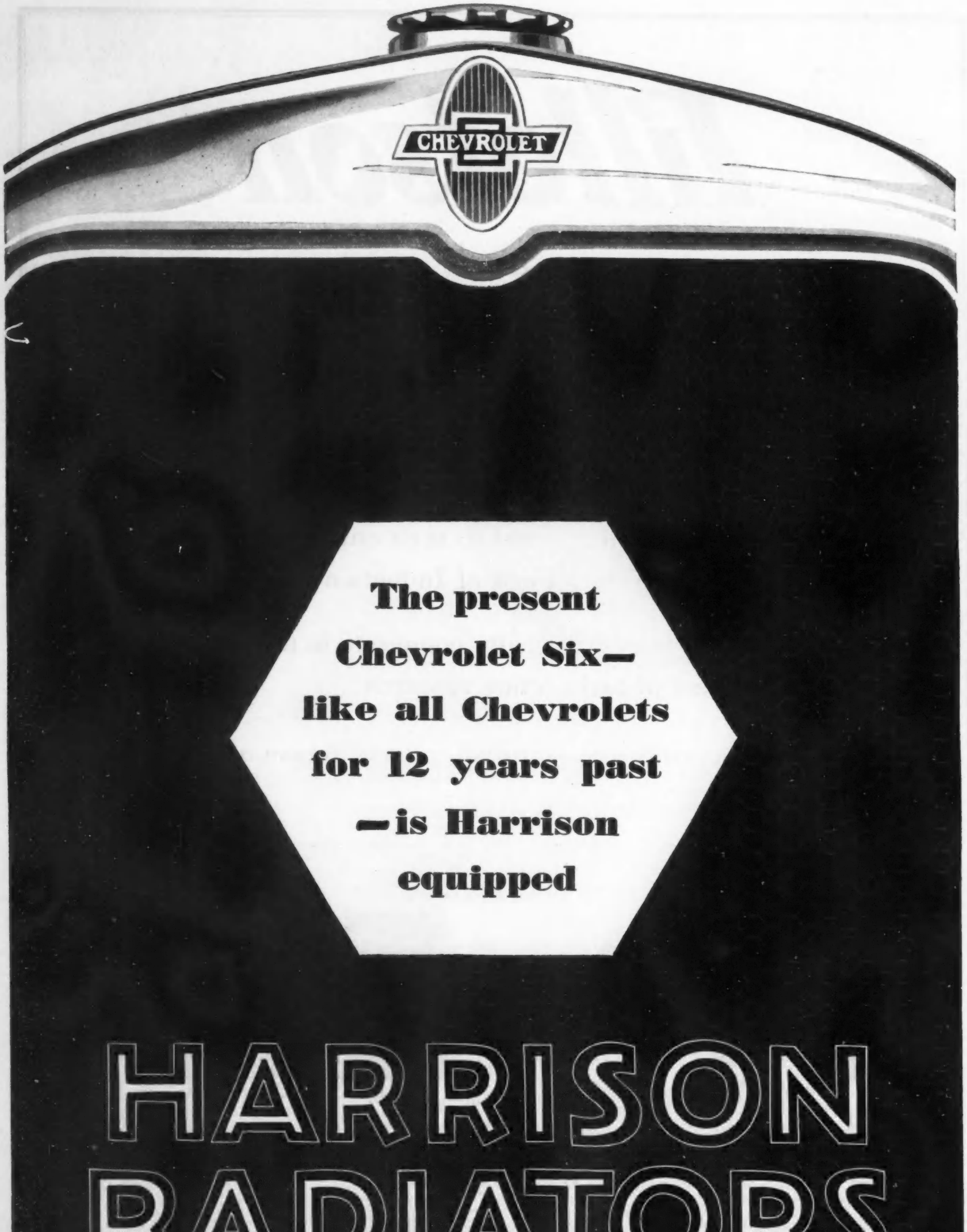
Frank W. Wilson is now connected with the Monroe Auto Equipment Co., of Monroe, Mich. He was formerly a student at the University of Michigan.

Louis G. Winkler has been advanced from the post of mechanical engineer to that of chief engineer with the Parts Corp., of Indianapolis.

William H. Wyckoff, formerly designing and layout engineer for Noble & Harris, consulting engineers, of Detroit, has become a designing engineer for the Edison Illuminating Co., of Detroit.

A. G. Zecher has accepted a position as equipment engineer with the Goldberg Bowen Co., of San Francisco. Formerly he was superintendent of motor-vehicles with the Walkup Drayage Co., of the same city.

R. C. Zeidler, until lately chief draftsman of the clutch division of the Long Mfg. Co., of Detroit, has been made assistant engineer of that company.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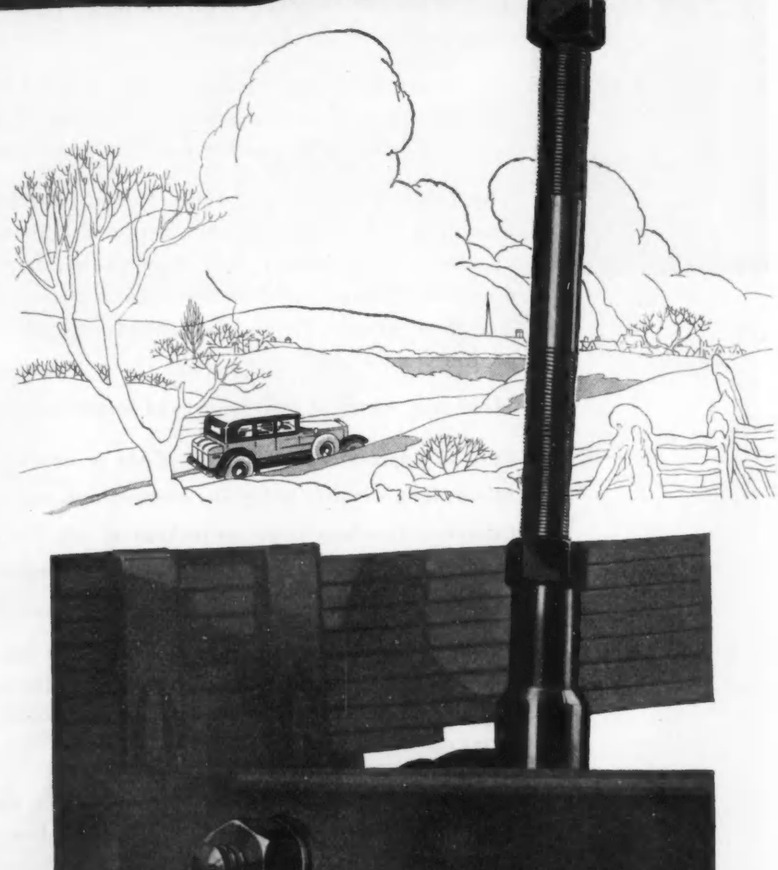

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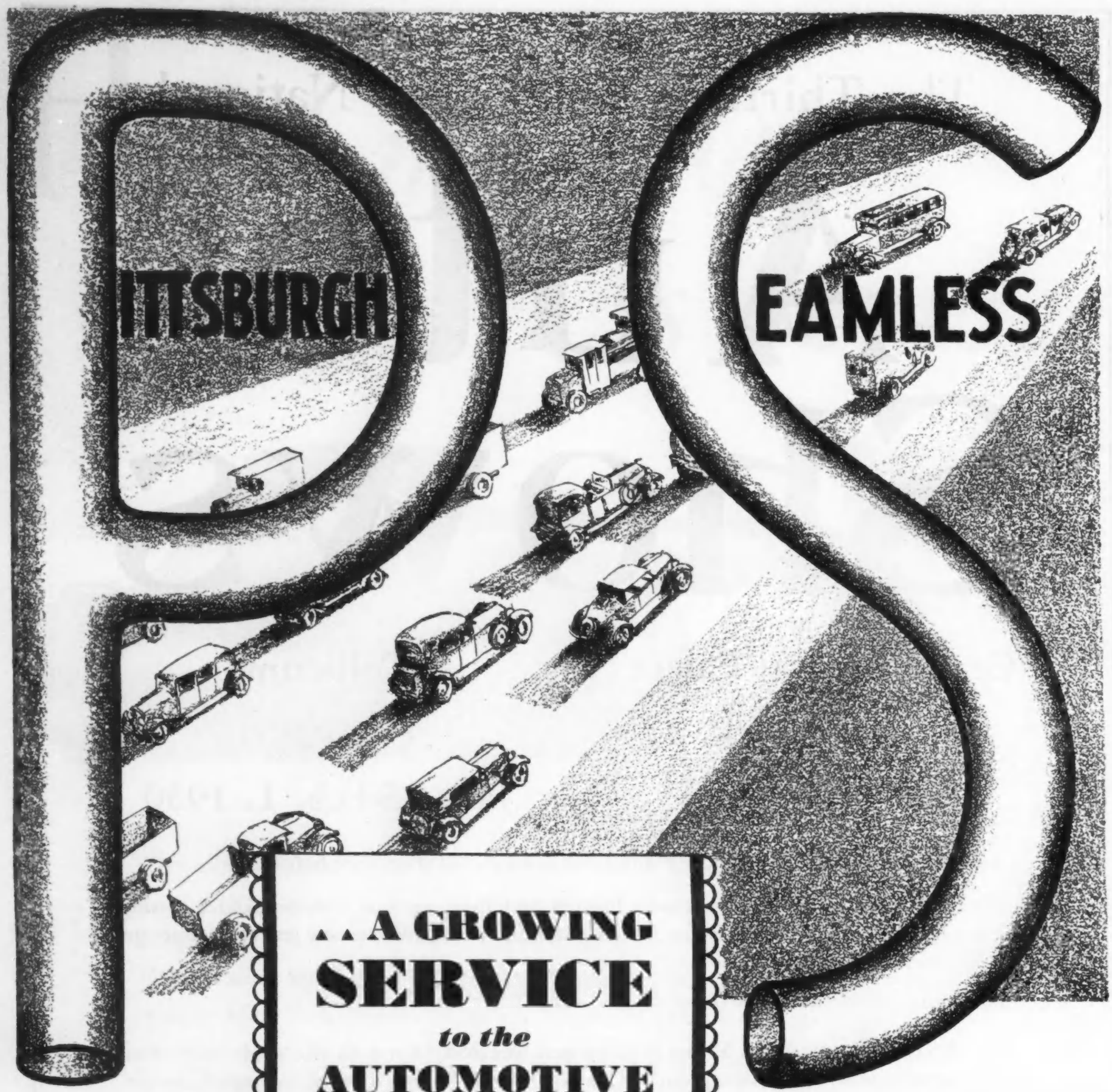
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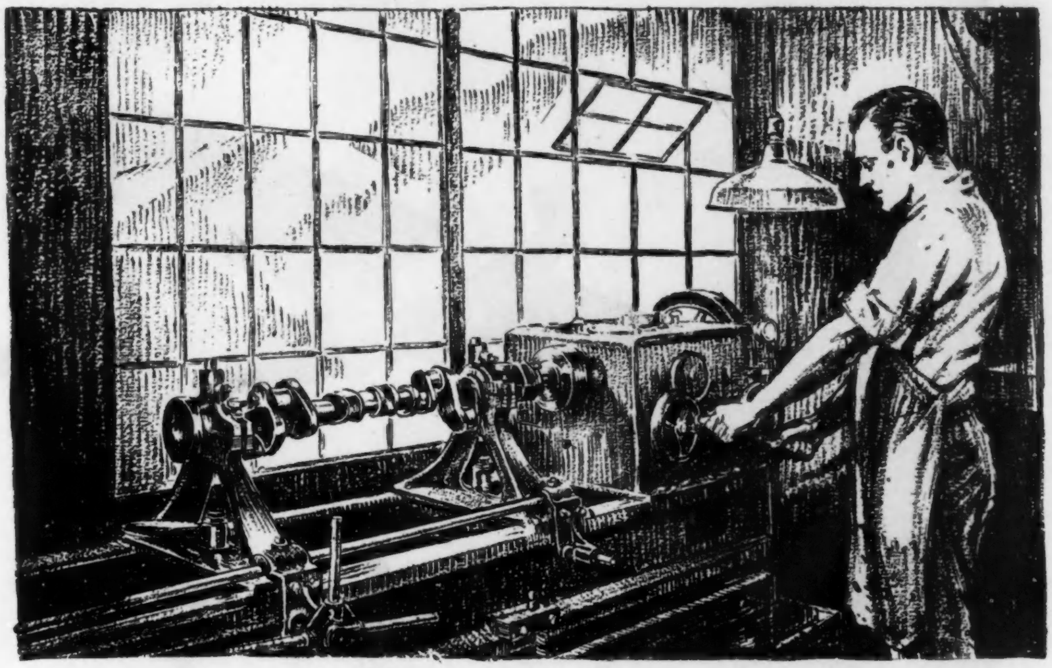

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"When checked for balancing, Normalized Carbon-Vanadium shafts showed an average amount out of balance of 3 to 5 oz. inches with an occasional shaft as high as 8 oz. inches. This is a great improvement over the type S. A. E. 1045 cranks which ran out as high as 15 or more oz. inches."

Normalized Carbon-Vanadium is an alloy steel of simple structure which develops high physical properties without heat treatment. Crankshafts of Normalized Carbon-Vanadium, therefore, are free from drastic cooling strains that result in quenching cracks, warpage and other defects. Once balanced, Normalized Carbon-Vanadium crankshafts remain balanced. Handling or aging does not cause spring or warpage. Cold straightening during machining is practically eliminated.

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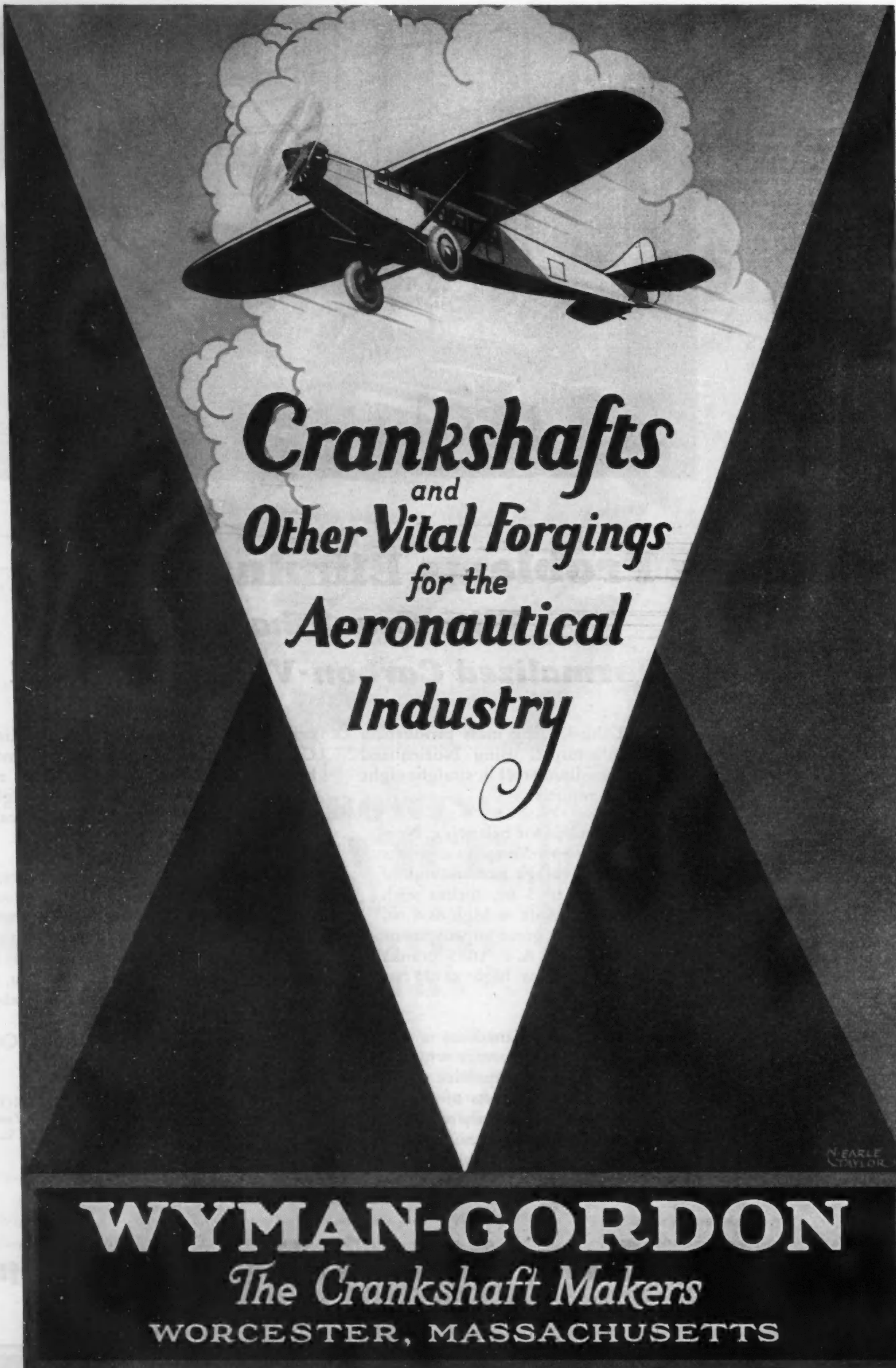

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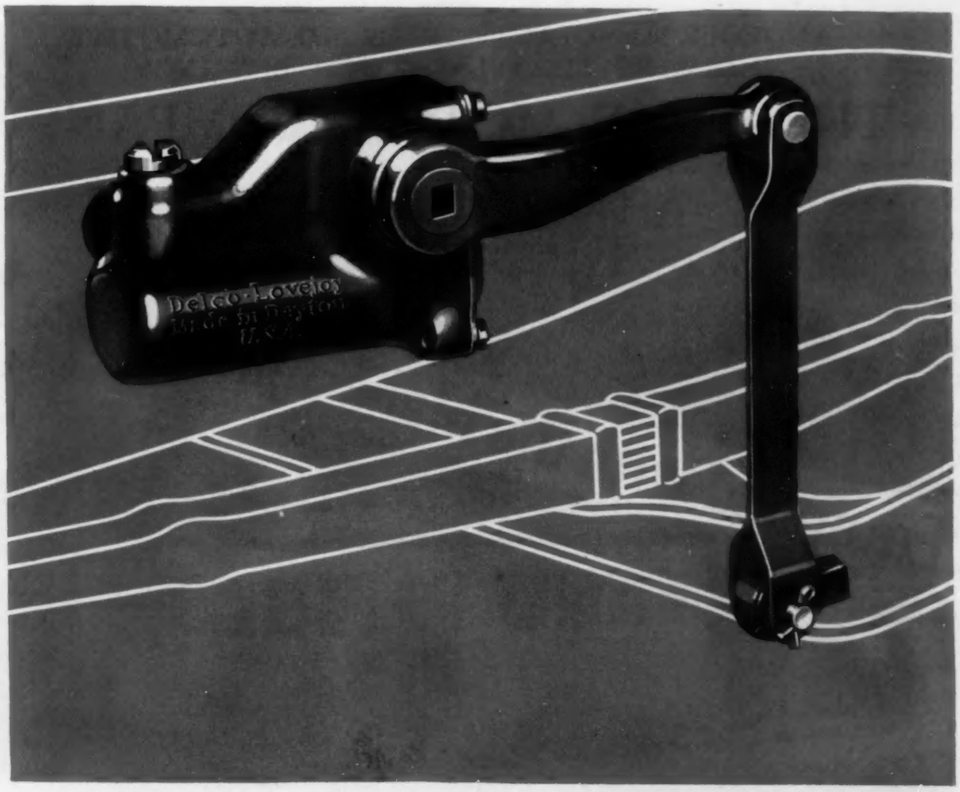
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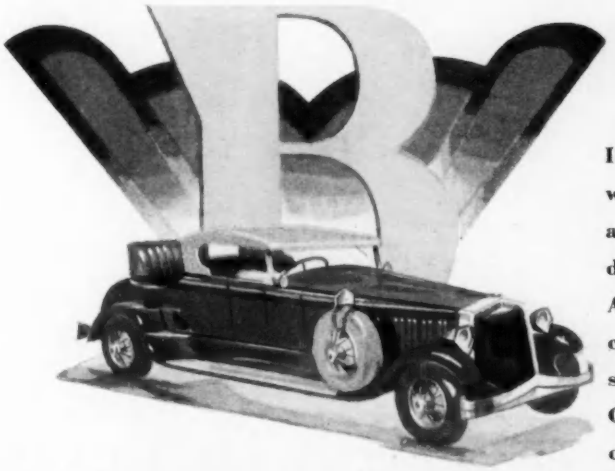


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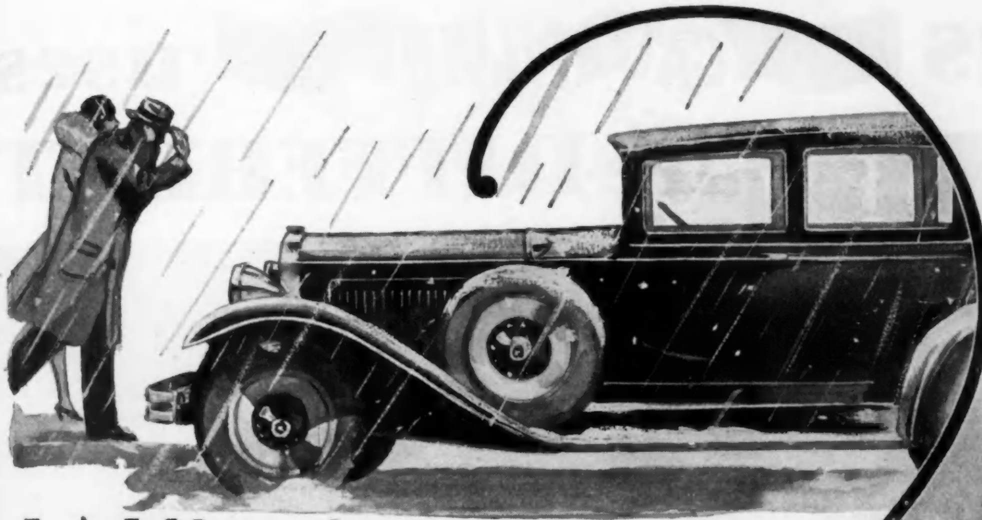

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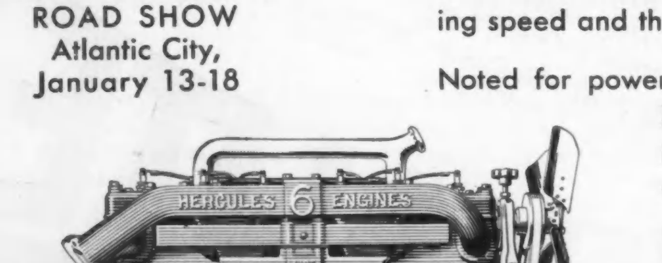
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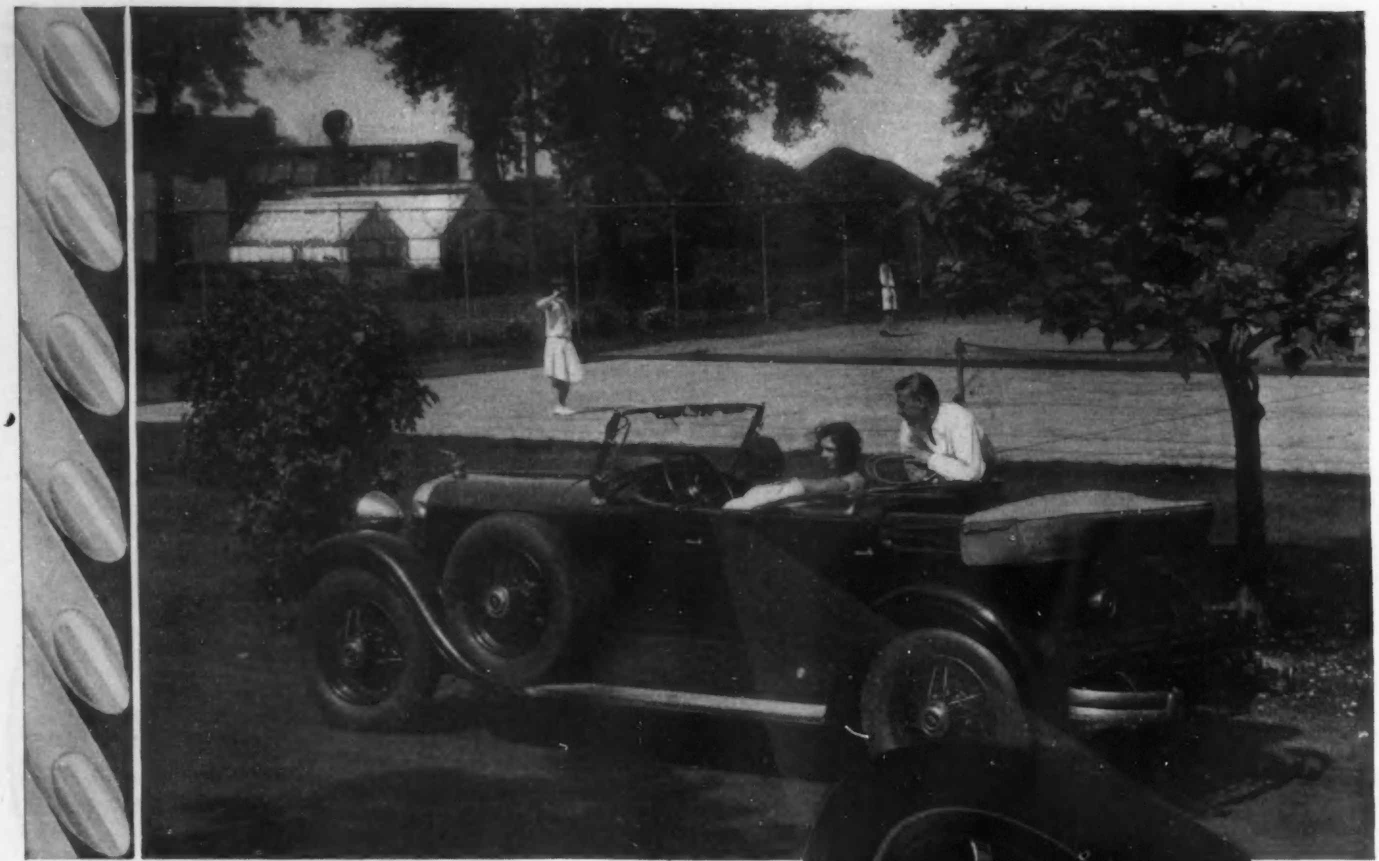


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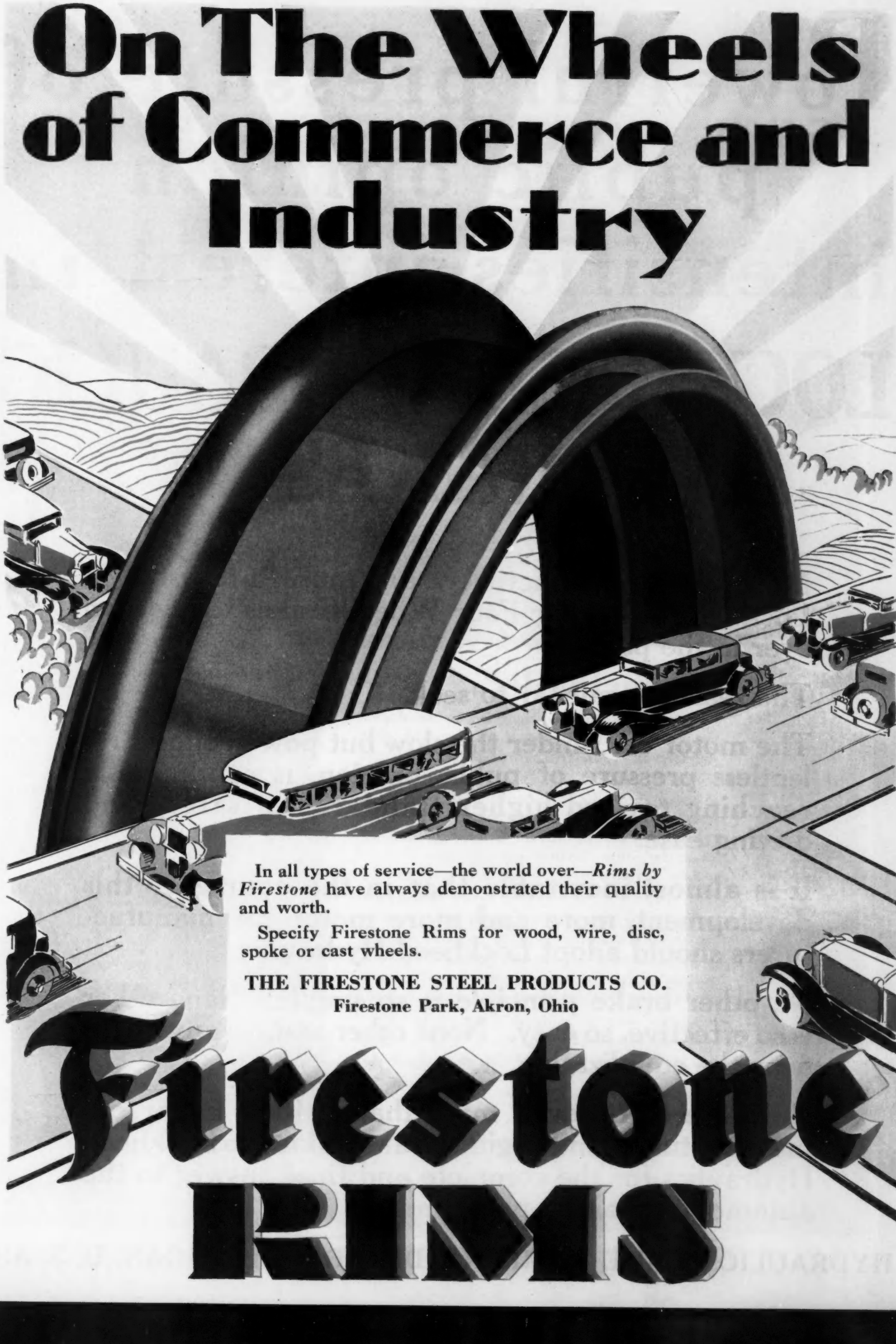
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Our Vice President in charge of sales won his spurs in production. He knows, and *what* he knows makes him an enthusiast. He is a member of our organization and therefore an indefatigable worker.

He meets the leaders of the industry with a smile and that pleases them—that they greet him with a smile pleases me.

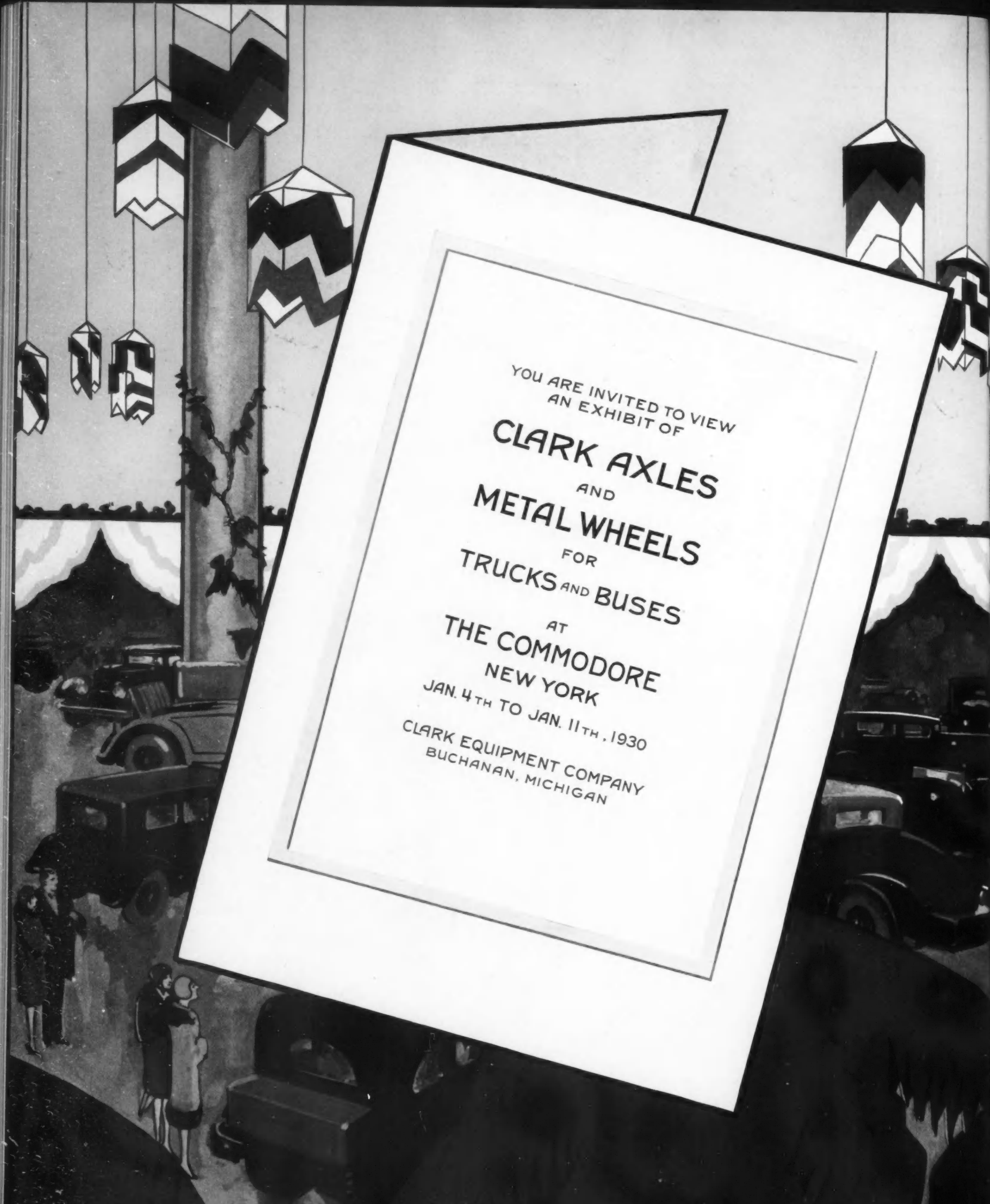
Eugene B. Clark.
President

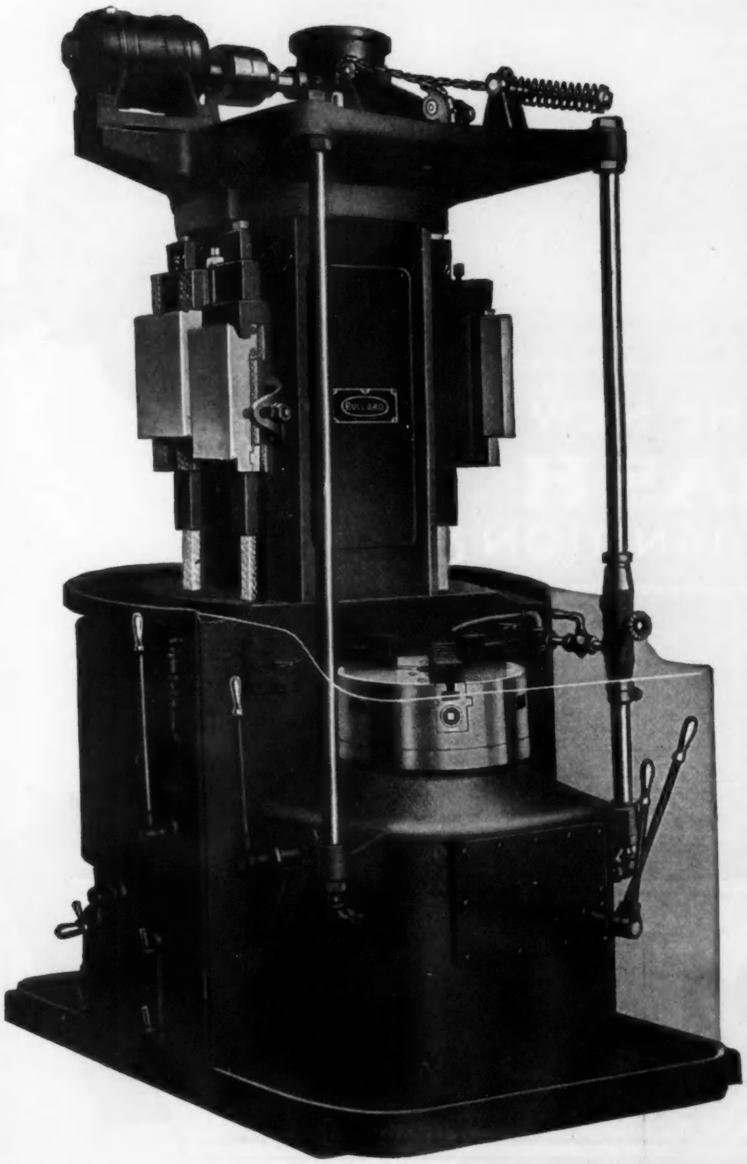
E. B. ROSS VICE PRESIDENT

Hail to the Chief

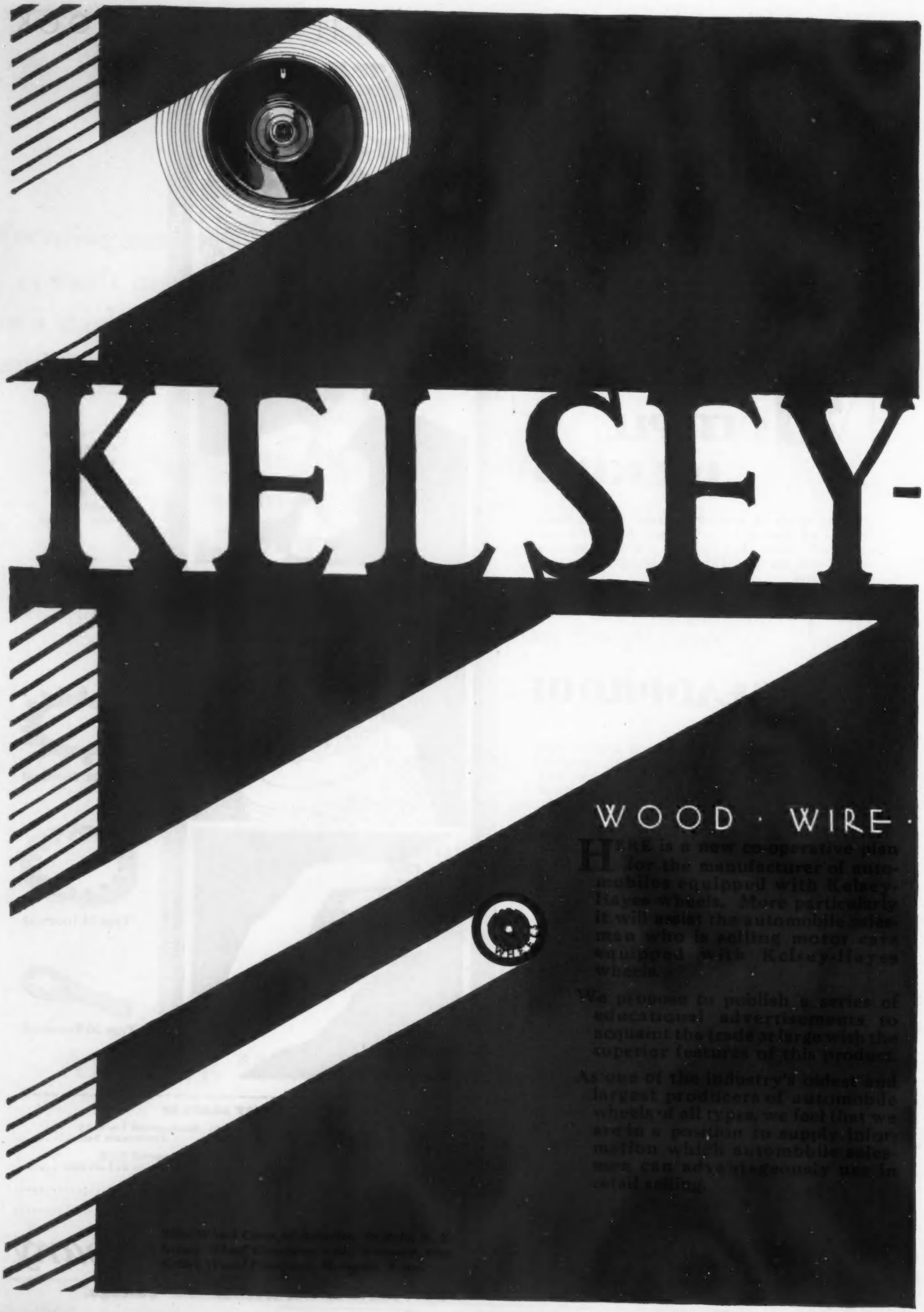
WE who have served through the years by the side of our president and friend want our industry to know the mark and measure of the man who by his tireless energy, indefatigable industry and abundant optimism has ever inspired our ambitions and led us forward to worthy achievements.

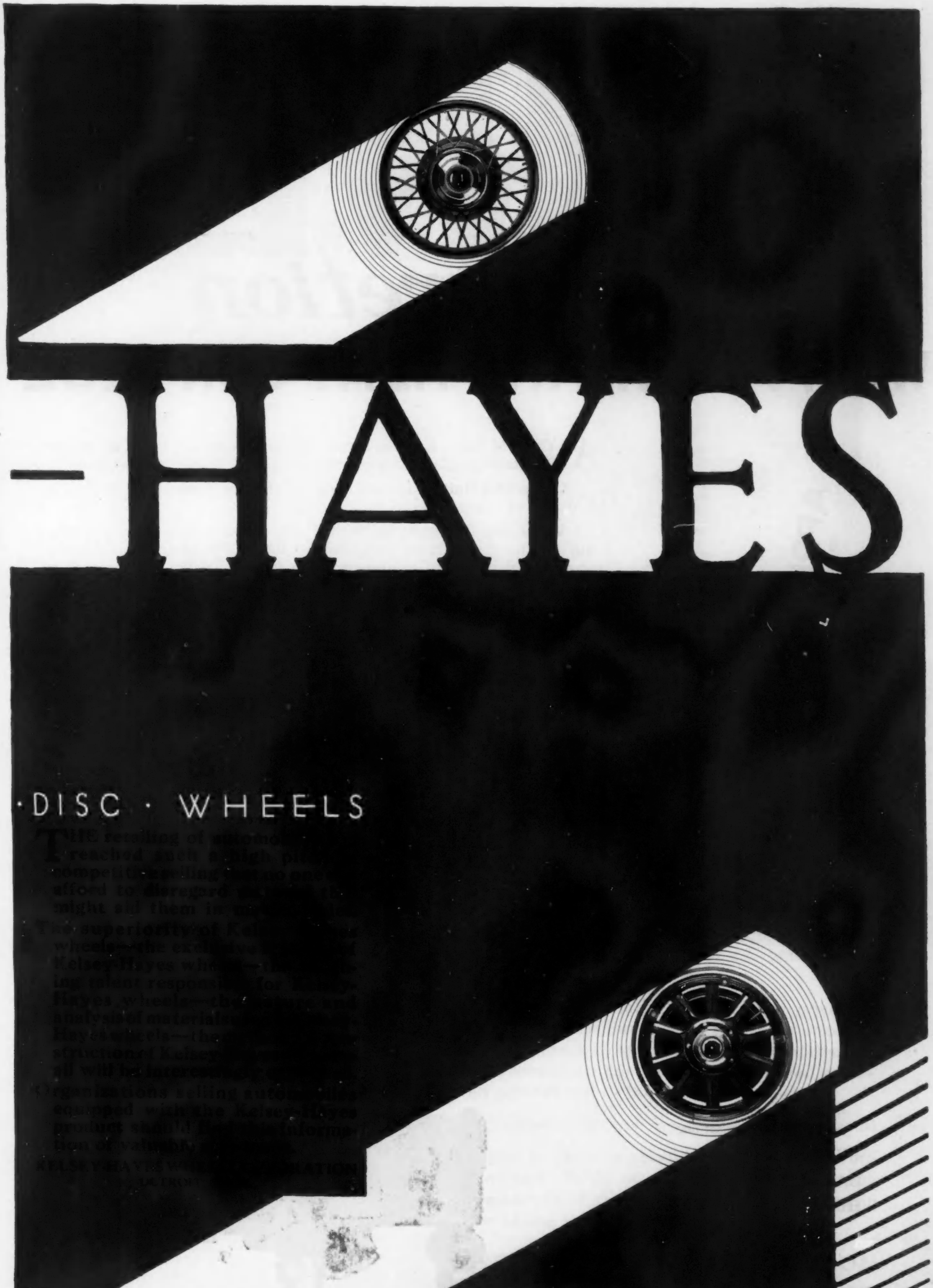
WE who have helped him build into American industry a great institution want the world to know what he has built within us.

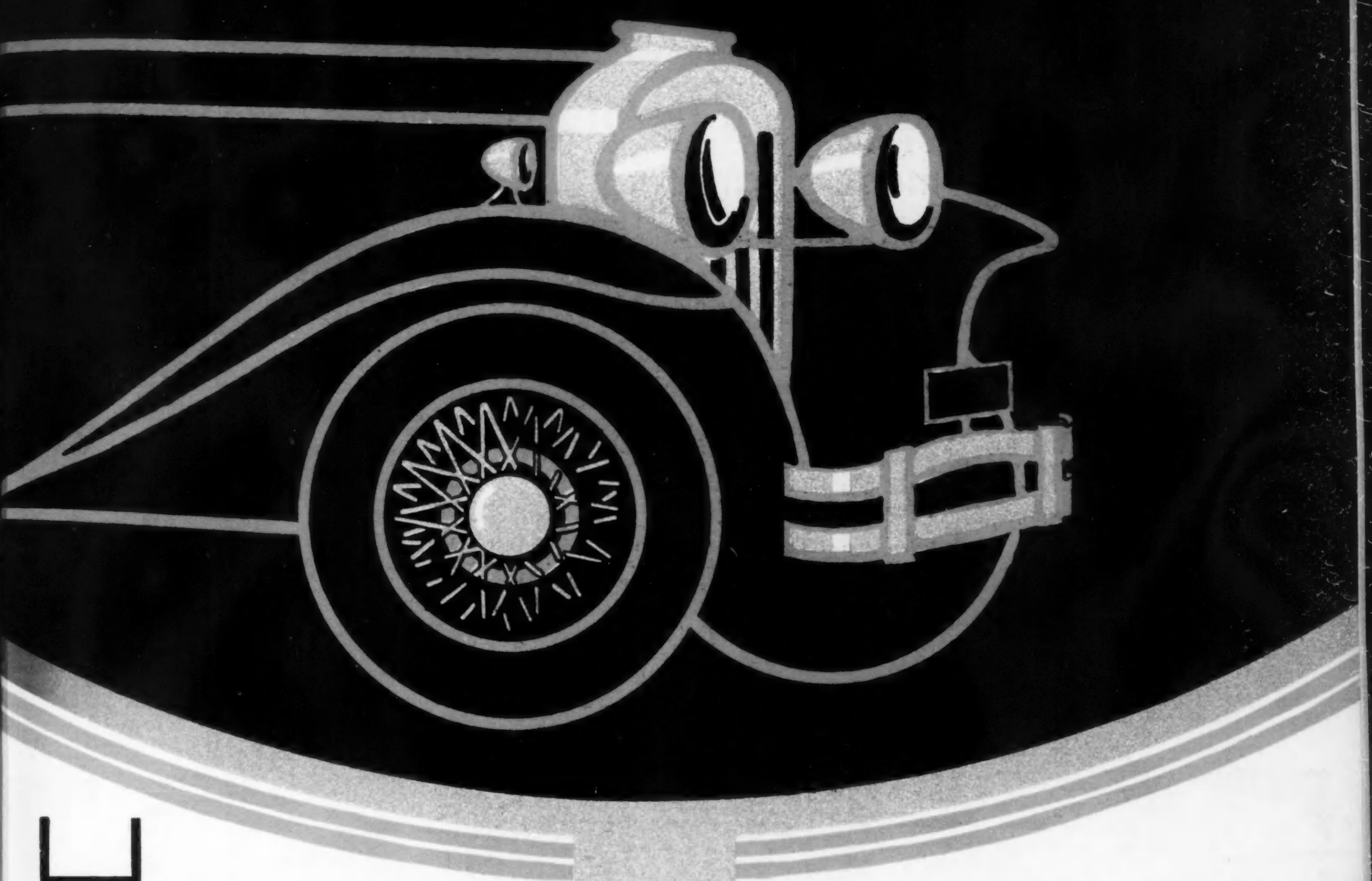

YOU ARE INVITED TO VIEW
AN EXHIBIT OF
CLARK AXLES
AND
METAL WHEELS
FOR
TRUCKS AND BUSES
AT
THE COMMODORE
NEW YORK
JAN. 4TH TO JAN. 11TH, 1930
CLARK EQUIPMENT COMPANY
BUCHANAN, MICHIGAN




THE
"400" SERIES
FOR 1930
THE NEW
NASH
TWIN-IGNITION 8
Modine
Turbotube RADIATORS


KELSEY-
WOOD · WIRE ·
HERE is a new co-operative plan for the manufacturer of automobiles equipped with Kelsey-Hayes wheels. More particularly it will assist the automobile salesman who is selling motor cars equipped with Kelsey-Hayes wheels.
We propose to publish a series of educational advertisements to acquaint the trade at large with the superior features of this product.
As one of the industry's oldest and largest producers of automobile wheels of all types, we feel that we are in a position to supply information which automobile salesmen can advantageously use in retail selling.


HAYES
·DISC · WHEELS



HOLDS ITS BRILLIANT MIRROR FINISH
for the LIFE-TIME *of a* CAR

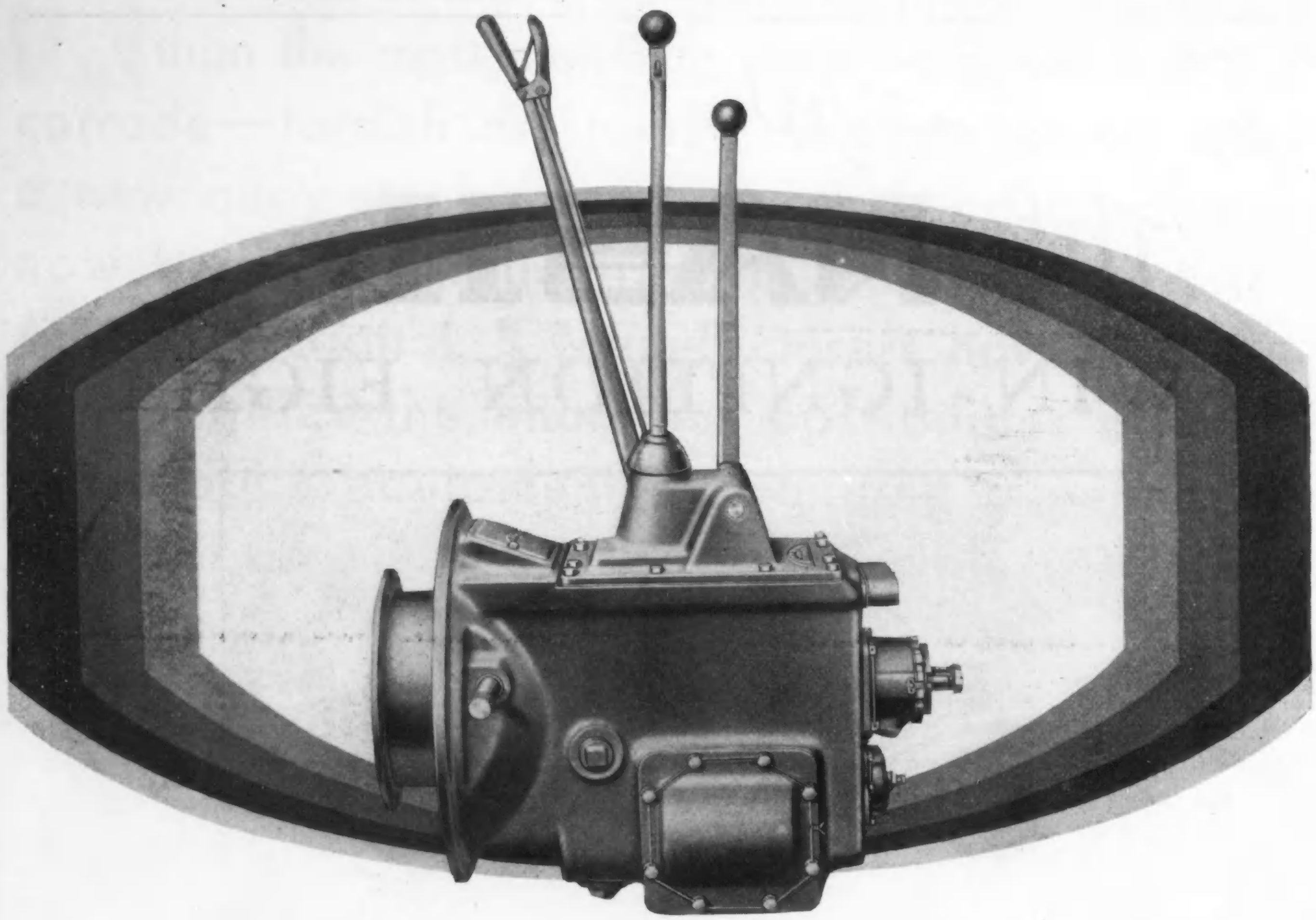
ENDURO NIROSTA KA2—a new—highly specialized alloy is finding wide favor in the automotive industry. ¶ For instrument panels—radiator shells and caps—hub caps—lights—bumpers—all equipment where a highly polished finish is desirable, Enduro fills the bill to perfection. ¶ For Enduro will not rust or corrode even under the most disadvantageous atmospheric conditions—and it requires no polishing or tiresome rubbing . . . Solid metal throughout, Enduro keeps its gleaming surface permanently ¶ Any of the companies mentioned below will be glad to discuss Enduro with you—at no expense or obligation on your part.

NIROSTA ENDURO K·A·2 STEEL

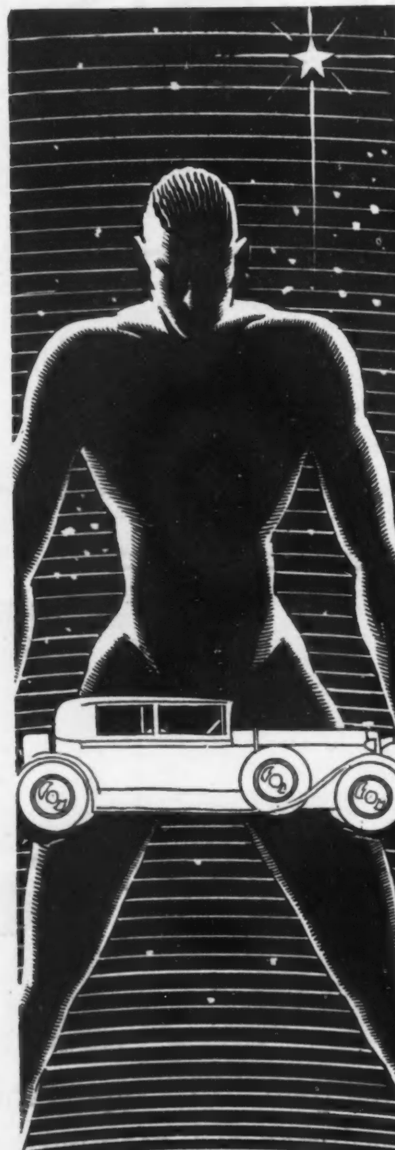
CENTRAL ALLOY STEEL CORP.
Massillon and Canton, Ohio

THE BABCOCK & WILCOX TUBE CO.
85 Liberty Street, New York City, N. Y.

LUDLUM STEEL CO.



★



SERVICE

THAT TAKES AN OCEAN IN ITS STRIDE

In 1924, American automobile manufacturers had been exporting cars to Europe for more than 20 years. Yet the rich foreign field was still largely fallow ground, waiting to be claimed and cultivated.

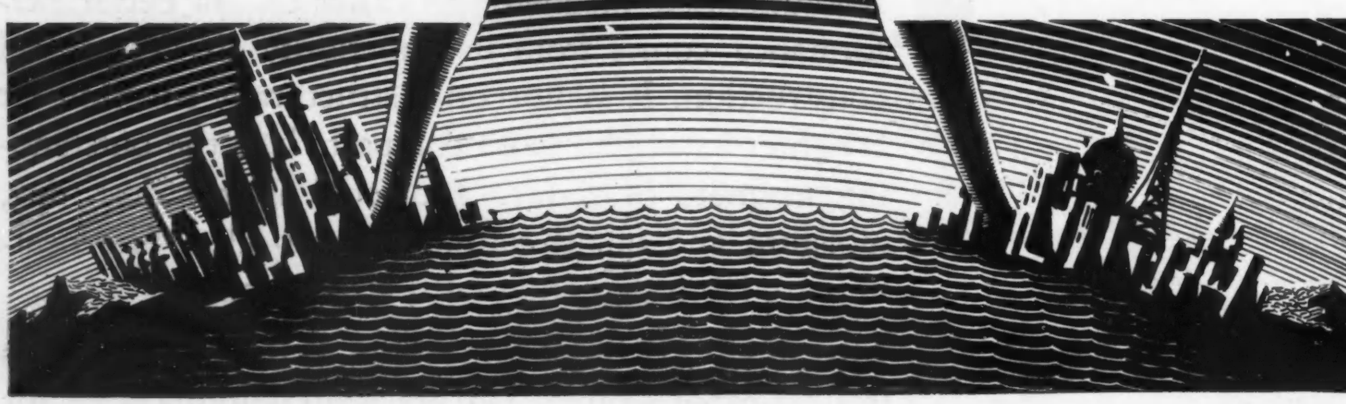
Budd looked beyond the horizon and realized that this day of intensive cultivation could not be far away. So Budd made ready for it.

Two years before any other American coach-maker had extended his operations beyond the American shore-line, Budd had built up foreign body-building facilities which then represented the largest American automotive investment in Europe. These facilities include complete coach-making plants at Oxford, England, and at Johannesthal, just outside Berlin.

Foreign manufacturers were quick to utilize this service. Europe's two largest builders of motor cars — Morris of England and Citroen of France — use Budd Bodies. And American manufacturers, too, have found that, through Budd's foreign service, they can purchase in Europe bodies identical to those they buy at home. This service enables them to assemble their cars in Europe and thus escape the heavy duties imposed on completely American-built automobiles.

The foresight and pioneering spirit which led to the establishment of these foreign plants is characteristic of the whole Budd organization. A company that will span an ocean to give American manufacturers better service abroad can be depended upon to do everything humanly possible to give these manufacturers a better coach-making service at home.

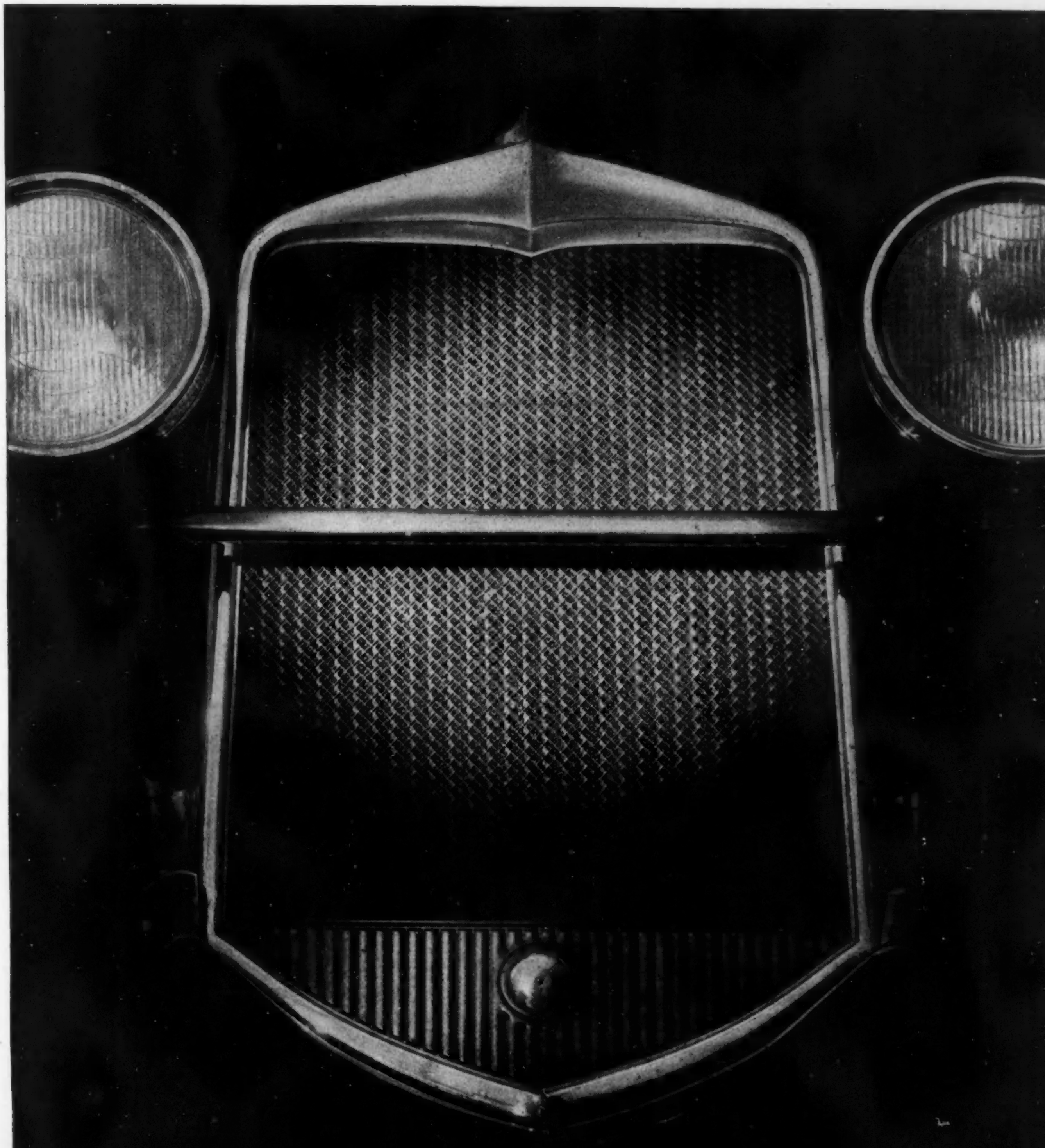
E. G. Budd Manufacturing Company, Philadelphia and Detroit. Affiliated with: The Pressed Steel Company of Great Britain; and Ambi-Budd Presswerke of Germany.



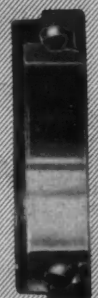
BUDD BODIES

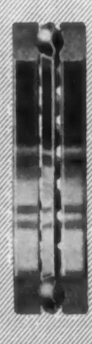
★ ★

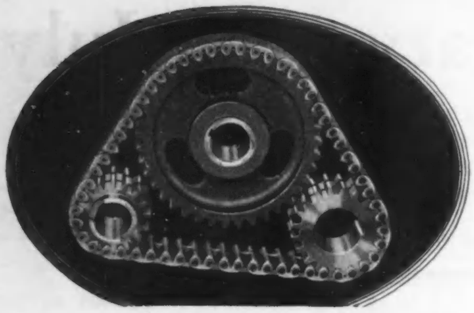
BUDD IS THE ONLY BODY BUILDER IN THE WORLD EQUIPPED TO BUILD ANY TYPE OF BODY




TEXTOLITE
STUDEBAKER







Annual Meeting

of the

Society of Automotive Engineers, Inc.

DETROIT, MICH.

January 20th to 24th, 1930

at the

Book-Cadillac Hotel

S. A. E. Annual Dinner

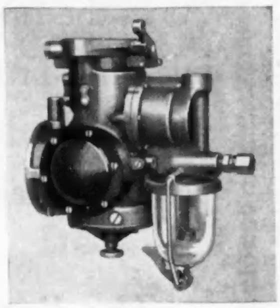
NEW YORK, N. Y.

January 9, 1930

HOTEL PENNSYLVANIA

(Reservation blanks will be mailed later)

For details regarding both events see the supplement in the text section of this Journal




UNIQUE THIN LEAD RED AMERICAN PENCIL CO. NEW YORK U.S.A. 1207
UNIQUE THIN LEAD BLUE-1206

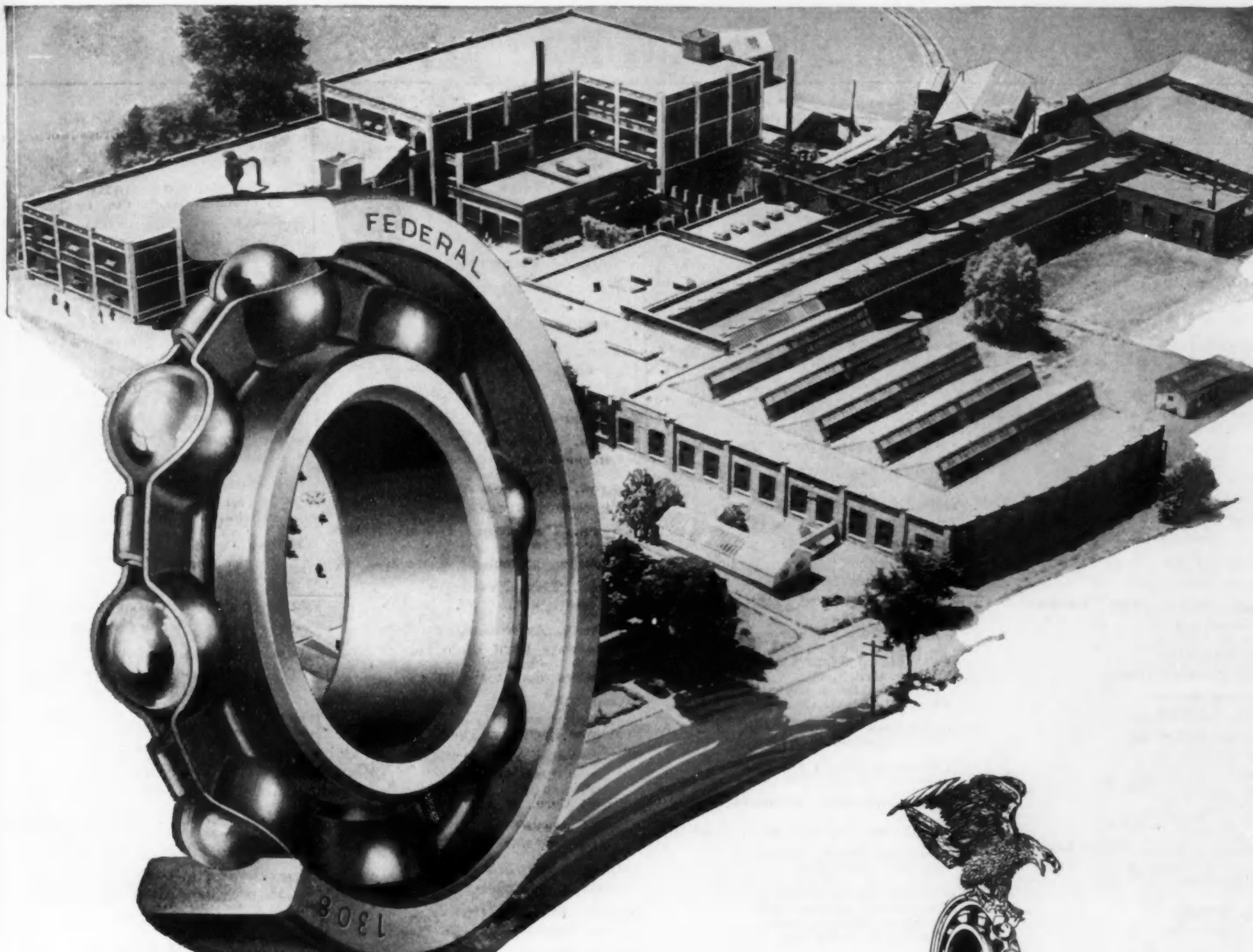
INDEX TO ADVERTISERS' PRODUCTS

(Continued on page 122)

Manufacturers of Products Conforming to S.A.E. Specifications

Advertisers whose products conform to S.A.E. spcifications are also listed in the S.A.E. Handbook List of Manufacturers, beginning on page 594, of the 1929 issue of the Handbook.

The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 128.



YEARS OF SPECIALIZATION

FOR MANY YEARS, this capable organization has been engaged in producing high-grade bearings exclusively. With specialization has come technical knowledge, skill and experience not always available to the average manufacturer of bearings.

THE "FEDERAL" executives, and engineers have one objective in view and that is to build a product which will sustain the "Federal" reputation for unmatched efficiency. A splendidly-equipped plant enables us to produce bearings of unequalled quality and performance.

We shall be pleased to forward samples, quotations and complete information to those interested

THE FEDERAL BEARINGS CO., INC., POUGHKEEPSIE, NEW YORK

Detroit Sales Office: 917 Book Building

FEDERAL

RADIAL BALL BEARINGS

INDEX TO ADVERTISERS' PRODUCTS

(Continued on page 124)

INDEX TO ADVERTISERS' PRODUCTS

Lubricating Systems
Adams Grease Gun Corp.
Alemite Mfg. Co.
Bijur Lubricating Corp.

Lugs, Soldering
Wolverine Tube Co.

Lugs, Terminal
Wolverine Tube Co.

Machines, Automatic Chucking
Bullard Co.

Machines, Automatic Multiple Spindle
Bullard Co.

Machines, Boring (Vertical)
Bullard Co.

Machines, Boring, Turning and Facing (Vertical)
Bullard Co.

Machines, Chucking
Bullard Co.

Machines, Chucking and Turning
Bullard Co.

Machines, Multiple Spindle
Bullard Co.

Machines, Power Transmission
Link-Belt Co.

Machines, Turret Automatic
Bullard Co.

Magnetos (Standard Mountings)
American Bosch Magneto Corp.
Bosch Magneto Co., Inc., Robert

Mats, Rubber
Goodrich Rubber Co., B. F.

Metal, Monel
International Nickel Co.

Mills, Vertical Boring and Turning
Bullard Co.

Molded Products, Phenolic Compound
General Plastics, Inc.

Moldings, Aluminum
Herron-Zimmers Molding Co.

Moldings, Steel
Herron-Zimmers Molding Co.

Moldings, White Metal
Herron-Zimmers Molding Co.

Moldings, Zinc
Herron-Zimmers Molding Co.

Molybdenum, Metallic
Vanadium Corp. of America

Mountings, Rubber
Goodrich Rubber Co., B. F.

Nails
American Steel & Wire Co.
Interstate Iron & Steel Co.
Parker-Kalon Corp.

Nickel
International Nickel Co.

Nuts
Columbus Bolt Works Co.
Shuler Axle Co., Inc.

Oil-Pumps
Kingston Products Corp.

Oils
Texas Company, The

Oscillographs
Southwark Foundry & Machine Co.

Ovens, Drying
Mahon Co., R. C.

Ovens, Electric
General Electric Co.

Packing, Asbestos
Goodrich Rubber Co., B. F.

Packing, Automotive
Delaware Hard Fibre Co.
Garlock Packing Co.

Packing, Water Pumps
Garlock Packing Co.

Paints, (See also Varnish, Enamel, etc.)
Arco Co.

Parts, Wood Body
Mengel Co.

Pencils, Drawing
American Lead Pencil Co.

Pinions
Delaware Hard Fibre Co.
General Electric Co.

Pinions, Starting-Motor
Electric Auto-Lite Co.

Pins, Cotter
Shuler Axle Co., Inc.

Pins, King
Thompson Products, Inc.

Pins, Leader
Danly Machine Specialties, Inc.

Pins, Piston
Thompson Products, Inc.

Pins, Steel Dowel
Danly Machine Specialties, Inc.

Pipe Fittings
Dole Valve Co.
Mueller Brass Co.
Titeflex Metal Hose Co.

Piping, Blower Systems
Mahon Co., R. C.

Piping, Exhaust Systems
Mahon Co., R. C.

Pistons, Aluminum
Aluminum Co. of America
Aluminum Industries, Inc.
Bohn Aluminum & Brass Corp.

Piston-Rings
Piston Ring Co.

Pots, Fire
Clayton & Lambert Mfg. Co.

Powder, Aluminum Paint
Aluminum Co. of America

Power-Packs, Radio
Kingston Products Corp.

Powerplants, Industrial
Waukesha Motor Co.

Power Take-Offs
Brown-Lipe Gear Co.
Fuller & Sons Mfg. Co.
Unit Corp. of America

Primers
Arco Co.
Dole Valve Co.

Propeller-Shafts
Spicer Mfg. Corp.

Pumps, Fuel
Stewart-Warner Speedometer Corp.

Pumps, Gas
Oakes Products Corp.
McCord Radiator & Mfg. Co.

Pumps, Starter
Kingston Products Corp.

Pyroscopes
Shore Instrument & Mfg. Co.

Radiators
G & O Mfg. Co.
Harrison Radiator Corp.
Long Mfg. Co.
McCord Radiator & Mfg. Co.
Modine Mfg. Co.

Reamers
Clark Equipment Co.
Whitman & Barnes Corp.

Regulators, Temperature
Dole Valve Co.

Relays, Cut-Out
North East Electric Co.

Retainers, Ball
Aetna Ball Bearing Mfg. Co.
Bearings Co. of America
Bossert Corp.

Rims, Airplane Tire
Firestone Steel Products Co.

Rims, Pneumatic Tire
Bethlehem Steel Co.
Cleveland Welding Co.
Firestone Steel Products Co.
Motor Wheel Corp.

Rims, Solid Rubber Tire
Bethlehem Steel Co.
Firestone Steel Products Co.

Rings, Welded Steel
Akron-Selle Co.

Rivets, Steel
Columbus Bolt Works Co.
Interstate Iron & Steel Co.

Rod, Aluminum
Aluminum Co. of America

Rod, Brake
Thompson Products, Inc.

Rod, Brass
Mueller Brass Co.

Rod, Bronze
Mueller Brass Co.

Rod-Ends
American Nut & Bolt Fastener Co.
Columbus Bolt Works Co.
Mansfield Lock Washer Co.
National Lock Washer Co.
Positive Lock Washer Co.
Reliance Mfg. Co.
Thompson Products, Inc.

Rod, Fibre
Delaware Hard Fibre Co.

Rod, Free-Cutting Brass
Mueller Brass Co.

Rod, Naval Brass
Mueller Brass Co.

Rod, Tie
Thompson Products, Inc.

Rod, Torque
Thompson Products, Inc.

Roller Bearings (See Bearings, Roller)

Roofing and Siding, Corrugated and Plain
New Jersey Zinc Co.

Roofing and Siding, Zinc Alloy
New Jersey Zinc Co.

Roofing, Metallic
Mahon Co., R. C.

Rubber, Strip
Goodrich Rubber Co., B. F.

Running Boards, Wood
Mengel Co.

Scleroscopes
Shore Instrument & Mfg. Co.

Screw-Machine Products
Akron-Selle Co.
Aluminum Co. of America
Barnes Co., Wallace
Dole Valve Co.
Link-Belt Co.
Mueller Brass Co.
New Process Gear Co., Inc.
Spicer Mfg. Corp.

Screw Threads
Dardelet Threadlock Corp.

Screws, Cap
Mechanics Universal Joint Co
Shuler Axle Co., Inc.

Screws, Drive, Steel
Parker-Kalon Corp.

Screws, Wood
Interstate Iron & Steel Co

Sets, Die
Danly Machine Specialties, Inc.

Shafts, Propeller
Pittsburgh Steel Products Co.
Spicer Mfg. Corp.

Shapes (Extruded Brass and Bronze)
Mueller Brass Co.

Shims
National Motor Bearing Co., Inc.

Shock-absorbers, Hydraulic
Delco Products Corp.
Gabriel Snubber Mfg. Co.

Shoes, Brake
Bossert Corp.

Shutters, Radiator
Pines Winterfront Co.

Snubbers
Gabriel Snubber Mfg. Co.

Spark Plugs
American Bosch Magneto Corp.

Speed Reducers
Link-Belt Co.

Speedometers
Motor Wheel Corp.

Spokes, Wood, Motor Truck
Motor Wheel Corp.

Spokes, Wood, Passenger Car
Motor Wheel Corporation

Spark Plugs
Bosch Magneto Co., Inc., Robert

Spraying Booths
Mahon Co., R. C.

Springs, Air
American Steel & Wire Co.

Springs, Coiled
American Steel & Wire Co.
Barnes-Gibson-Raymond, Inc.
Cleveland Wire Spring Co.
Cook Spring Co. Division
Danly Machine Specialties, Inc.
Gibson Co., Wm. D.

Springs, Flat
American Steel & Wire Co.
Barnes Co., Wallace
Barnes-Gibson-Raymond, Inc.
Cleveland Wire Spring Co.
Cook Spring Co. Division
Gibson Co., Wm. D.

Springs, Leaf
Standard Steel Spring Co.

Sprockets, Block Chain
Whitney Mfg. Co.

Sprockets, Roller-Chain
Link-Belt Co.
Whitney Mfg. Co.

Sprockets, Silent-Chain
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

Stampings
Akron-Selle Co.
Barnes Co., Wallace
Bossert Corp.
Clayton & Lambert Mfg. Co.
Cook Spring Co. Division
Motor Wheel Corp.
Oakes Products Corp.
Rochester Mfg. Co., Inc.
Spicer Mfg. Corp.

Starter-Generators
North East Electric Co.

Starting-Motors (Standard Mountings)
Bosch Magneto Co., Inc., Robert
Electric Auto-Lite Co.
Leece-Neville Co.
North East Electric Co.

Steel, Alloy
Bethlehem Steel Co.
Central Alloy Steel Corp.
Donner Steel Co., Inc.
Enduro Nirosta Steel
Illinois Steel Co.
Interstate Iron & Steel Co.
Timken Roller Bearing Co.

Steel, Carbon
Barnes Co., Wallace
Bethlehem Steel Co.
Central Alloy Steel Corp.
Donner Steel Co., Inc.
Illinois Steel Co.
Interstate Iron & Steel Co.
Timken Roller Bearing Co.

Steel, Cold Drawn
American Steel & Wire Co.

Steel, Electric Furnace
Timken Roller Bearing Co.

Steel, Leaf Spring
Central Alloy Steel Corp.

Steel, Molybdenum
Central Alloy Steel Corp.

Steel, Non-Corrosive
Bethlehem Steel Co.

Steel, Open Hearth
Timken Roller Bearing Co.

Steel, Rivet
Bethlehem Steel Co.
Illinois Steel Co.
Interstate Iron & Steel Co.

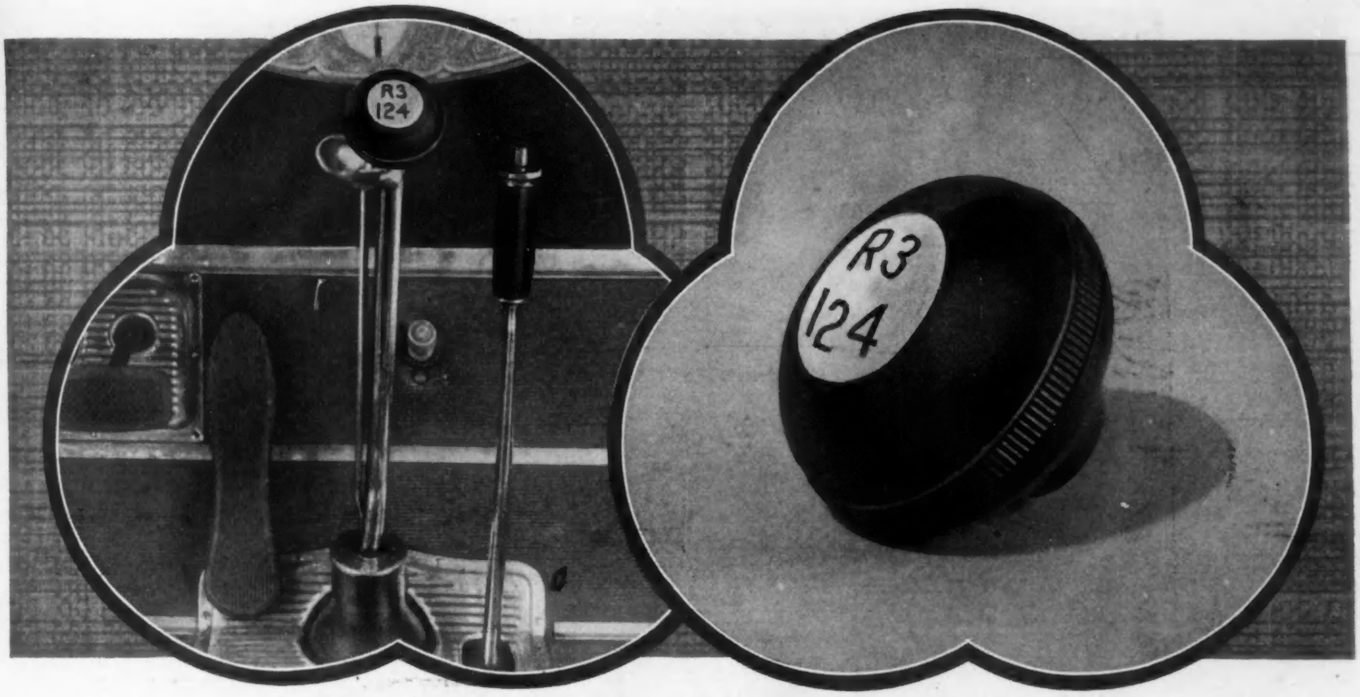
Steel, Sheet
National Association of Flat Rolled Steel Manufacturers

(Concluded on page 126)

INDEX TO ADVERTISERS' PRODUCTS

INDEX TO ADVERTISERS

The Index to Advertisers' Products is given on pages 120, 122, 124, and 126



Gear shift lever ball of Bakelite Molded used on Graham-Paige cars.

Bakelite Molded again proves its adaptability to special requirements

THIS gear shift lever ball is unusual in that it has a circular metal disc inset in the top to indicate the various gear shifts. The disc is formed with a stem at the back, and is held in place by a lock nut within the ball.

The Bakelite Molded ball is formed in one press operation, with an accurately dimensioned recess for the disc, a hole through the center for the stem, and a threaded metal insert in the bottom for attaching it to the shift lever. Its smooth, lustrous surface and the milled band around the center are also acquired in the mold. No subsequent polishing or machining are required.

Bakelite Engineering Service

Intimate knowledge of thousands of varied applications of Bakelite Materials combined with eighteen years' experience in the development of phenol resinoids for automotive uses provides a valuable background for the cooperation offered by our engineers and research laboratories. *Write for Booklet 5-M, "Bakelite Molded."*

BAKELITE CORPORATION

247 Park Avenue, New York, N. Y. Chicago Office, 635 West 22nd Street
BAKELITE CORPORATION OF CANADA, LTD., 163 Dufferin Street, Toronto, Ont.

BAKELITE

REGISTERED U. S. PAT. OFF.

THE MATERIAL OF A THOUSAND USES

"The registered Trade Mark and Symbol shown above may be used only on products made from materials manufactured by Bakelite Corporation Under the capital "B" is the numerical sign for infinity, or unlimited quantity It symbolizes the infinite number of present and future uses of Bakelite Corporation's products."